

T H E
P H I L O S O P H Y
O F 8716 B10
Sir ISAAC NEWTON

EXPLAINED,
IN SIX DIALOGUES,
O N
L I G H T and C O L O U R S,
Between a LADY and the AUTHOR.

B Y
C O U N T A L G A R O T T I,
F. R. S. F. S. A. 7/6

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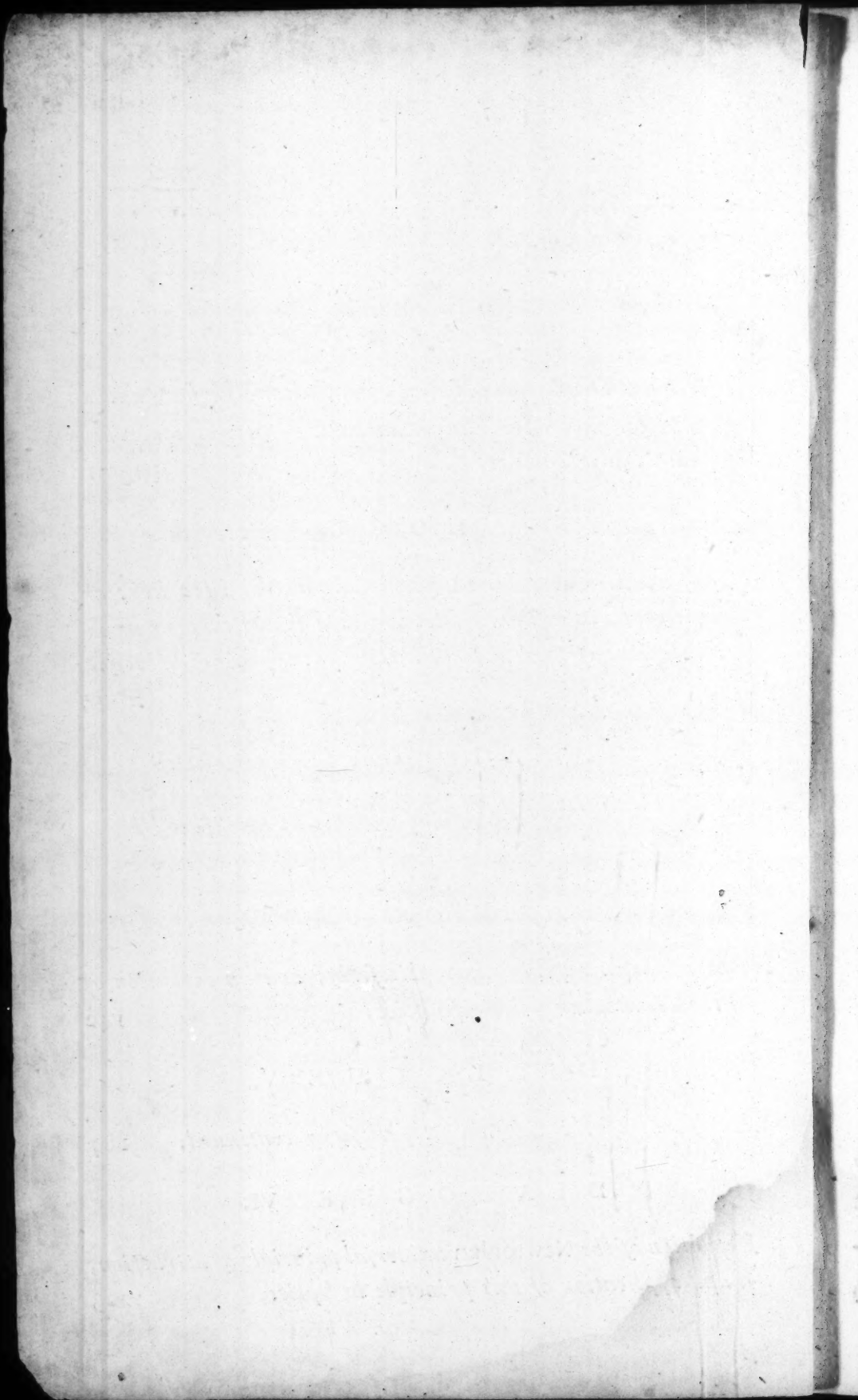
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T O

Monf. de FONTENELLE.

IF you addrested your ingenious and entertaining Dialogues to the illustrious Dead, who had first given you the idea of that work, and therefor thought yourself obliged to seek your Hero even in the obscurity of the tomb; how much greater reason have I to dedicate these discourses to one of the most illustrious among the Living, whom I am indebted to for the example which set me upon composing them, and who has given me so perfect a model of polite wit and agreeable writing?

Your Plurality of Worlds first softened the savage nature of philosophy; and called it from the solitary closets and libraries of the learned, to introduce it into the circles and toilets of

A

ladies. You first interpreted to the most amiable part of the universe those hieroglyphics, which were at first only for initiates; and found a happy method to imbellish and intersperse with most beautiful flowers a field, which once seemed incapable of producing any thing but the most rugged thorns and perplexing difficulties. You may be said to have committed the care of revolving the heavens to Venus, and the Graces, instead of those intelligences to whom ignorance had anciently assigned that office.

The success was answerable to the beauty and novelty of the undertaking. That half of our world, which always commands the votes of the other, has given its approbation to your book, and in the most agreeable manner consecrated it to posterity.

May I venture to flatter myself, that my Light and Colours will have the same fate as your Worlds? If a desire of pleasing those who afford us so

much pleasure, were sufficient to make its fortune, I should have nothing to envy you. But I am too sensible of the very many defects that attend my performance, defects that I cannot help lamenting; for not to say any thing of your talents, and that happy art of rendering every thing you undertake entertaining and agreeable, the plurality of Worlds, which you have chosen for your subject, seems of all others to present the most pleasing and elegant images, and is therefor the most agreeable to your dialogists, that the vast field of philosophy could ever supply you with. It presents to the mind nothing less than the stars and planets, the noblest and most shining objects of the universe. There are but few of the subtle enquiries of science, into which you are obliged to enter. The arguments, upon which your opinion is founded, do not carry such a certainty in them, as to make the conversation grow languid.

I have endeavoured to set truth, accompanied with all that is necessary to demonstrate it, in a pleasing light, and to render it agreeable to that sex, which had rather perceive than understand. Light and Colours are the subject of my dialogues; a subject, which, however lively and agreeable it may seem, is not in itself either so pleasing or so extensive as your worlds. I am obliged to descend to many difficult and minute particulars of knowledge; and my arguments are unhappily incontestible experiments, which must be explained with the greatest accuracy imaginable. It was indeed just, that the ladies, who by your work had been made acquainted with the great change introduced by Des Cartes into the thinking world, should not be ignorant of the new, and, it is probable, the last change, of which the illustrious Sir Isaac Newton was the author. But it was extremely difficult to civilize this savage philosophy, which

in the paths of calculation and the most abstruse Geometry was returning more than ever to its ancient austerity. You have embellished the Cartesian philosophy; and I have endeavoured to soften the Newtonian, and render its very severities agreeable.

However, the abstruse points, upon which I have been obliged to treat, were only such as are absolutely necessary, and always interspersed with something that may relieve the mind from that attention which they require. In the most delightful walk we are sometimes glad to find a verdant turf to repose ourselves upon. Lines and mathematical figures are entirely excluded, as they would have given these discourses too scientific an air, and appeared formidable to those, who to be instructed must be pleased. Mathematical terms are as much as possible avoided; and if ever any do occur, they are explained by the assistance of the most familiar objects. The difficulties

raised against any particular experiment, the history of optical inventions, metaphysical doubts, and the various opinions of different philosophers, preserve the subject from that continued uniformity, which would make it disagreeable and tedious. I have endeavoured as much as possible to render it lively, and make my readers interest themselves in it as they would in a composition for the theatre. Is there any thing, especially where ladies are concerned, in which a writer should omit any endeavours to move the heart?

The marvellous, of which the heart, always desirous of being affected, is so fond, happily arises in true philosophy of itself, without the help of machines. I have made a sort of change or catastrophe in the philosophy of my Marchioness, who is at first a Cartesian, afterwards a profelyte to Malebranche, and at last obliged to embrace the system of that person, who ought to be

placed at the head of his species, if superiority and rank among mankind were determined by strength of genius and the most comprehensive knowledge. This great philosopher's general system of attraction is not omitted, because it has a natural connexion with the particular attraction observed betwixt bodies and light. Thus these dialogues may be considered as a complete treatise of the Newtonian philosophy. The sanctuary of the temple will always be reserved for the priests and favourites of the Deity; but the entrance and its other less retired parts will be open to the profane.

The stile I have endeavoured to follow is what I believed most proper for dialogue, clear, concise, interrupted, or interspersed with images or turns of wit. I have taken the utmost care to avoid those perplexed and long periods closed by the verb, which only serve to run the reader out of breath, and are beside repugnant to good sense, and

much less agreeable to the genius of our language than is generally believed, and certainly cannot be agreeable to the genius of those, who write with an intention of being understood. I have left them entirely to those, who forsake the *Saggiatore for the †Fiammetta, together with those antique and obsolete words which constitute so great a part both of their knowledge and delight. The Count di Castiglione, in his Courtier, two centuries ago, ventured to write in such a manner, as to be understood by his contemporaries, and throwing aside the affectation of Gothic terms, adapted his manner of writing to the forms of speech in use among the polite and well-bred persons of his time. Custom the sovereign judge in all languages, except perhaps our own, was his guide; and thus he enriches us with the finest piece, as far

* An Epistle from *Galileo* to *Virginus Caesarinus*, in which the author gives a very elegant exposition of his system of Physics and Astronomy

† A Romance, by *Boccace*.

as regards the style, which the Italian language has to boast of. For what reason should I think myself obliged to make use of the antiquated discourses of some clamorous haranguer of four hundred years standing, as a model for a work of philosophy and politeness; and rather than talk to ladies in the language of the present age, address my discourse to the devotees of the thirteenth century?

This minute dissertation I thought in some measure due to yourself, to let you see how little I have neglected in a manner of writing, which may be regarded as your own. Nor was it less due to my countrymen, since this work, whatever it be, is written in their original language. Young mathematicians, in giving the solution of a problem, generally describe the steps by which they investigated it: it is only those of an established reputation who are permitted to give the simple solution, and leave to others the

care of finding by what means they attained it.

I would not however appear to set a greater value upon this work than perhaps the world will think it deserves, or suppose myself to have given a perfect solution of this problem. I am too well acquainted both with myself, and the difficulty of the enterprize, to entertain so high an opinion of the performance. I have perhaps only seen the method, which ought to be followed, and yet have not followed it myself. Raphael and Guercino had nearly an equal knowlege of the preparations necessary for the right designing of a figure, and yet were extremely unequal in the execution of it.

Whatever may be the success of my undertaking, the ladies, for whom this work is principally intended, ought at least to think themselves obliged to me, if I have procured to them a new kind of amusement, which others may perhaps carry to a greater degree of perfection; and if I have brought into

Italy a new mode of cultivating the mind, rather than the present momentary fashion of adjusting their head-dress and placing their curls. Travellers should be the importers of wit, and of those reciprocal advantages, which different nations even in this respect have over each other. Happy the society formed upon the Italian fancy, the French politeness, and British good sense!

We ought to think ourselves obliged to your nation, and yourself in particular, for giving us an example to render common and easy what was once mysterious and difficult, and to write in our own language what by a superstitious veneration was appropriated to the Latin, and at the same time perplexed with Greek, that most formidable weapon of pedantry. We may in this respect cast the same reproach on the Italians as Mr. Pope does in another case on the English in his fine prologue to Cato.

*Our scene precariously subsists too long
On French translation and Italian song.*

*Dare to have sense yourselves, assert the stage,
Be justly warm'd with your own native rage.*

If we except some translations from the French, there is nothing among us but songs and collections of verses, which every day overspread us like a deluge, and are the torments of our age. In the modern books, written in the Italian language, the ladies can find nothing but sonnets full of a metaphysical love, which I suppose must affect them as little as the antiquated expressions of superannuated Cicisbei. Let the age of realities once more arise among us, and knowledge instead of giving a rude and savage turn to the mind, and exciting endless disputes and wrangling upon some obsolete phrase, serve to polish and adorn society. I have at least opened the way to something, which is neither grammar nor sonnet; and I shall flatter myself to have done much more, if what the ladies inspired me with, has the good fortune to meet with your approbation.

DIALOGUES

ON

LIGHT and COLOURS.

DIALOGUE I.

A general idea of Physics, and an explanation of the most remarkable hypotheses concerning Light and Colours.

THE very same reason that led me every day to a concert of music, a gay and elegant entertainment, a ball or the theatre, induced me to write an account of the manner in which I passed my time last summer in the country with the marchioness of E—, and has thus, from an idle and useless member of society, rendered me an author. And the natural desire that every author has to appear in print (whatever these gentlemen may tell us in their long prefaces) engages me at present to publish this account. It is entirely philosophical, and composed of certain discourses which I had with that polite lady on the subject of Light and Colours. Some will, I make no doubt, condemn me for having passed my time so ill with a lady; and indeed I have condemned myself for it. But if they knew what an engaging manner the marchioness has of obliging every one to what she desires, I am persuaded they would forgive me, even if I had read her Guicciardini's * history of the wars of Pisa, if she could have desired it. But however inexcusable my error might be, I constantly endeavoured to amend it, whenever I could

* An Italian historian very prolix and tedious. It was a saying of Dr. Donne's, that if Moses had wrote like Guicciardini, the whole world would not have been big enough to contain the history of its own creation.

disengage myself a little from Light and Colours: and indeed both the beauty of the marchioness, and the nature of the place, which seemed formed to support what she had every where given birth to, inspired a discourse quite different from that of philosophy. The little peninsula of Sirmione, the country of the polite Catullus, and those mountains which have so often repeated the fine verses of Fracastorius *, two remarkable points, if I may use the expression, in the poetical geography, formed a distant prospect to a fine seat, placed on an easy ascent, that was watered below with the clear streams of the Benaco †, which by its great extent, and the roling of its waves, seems to rival the ocean. The orange trees that diffused their odours along the banks, and perfumed the air all around with a delightful fragrance, the coolness of the woods, the murmur of fountains, the vessels that spread their sails along the chrystal lake, each of these agreeable objects would have alternately ravished my senses, if the goddess of this delightful place had not wholly engaged my attention.

To the charms of wit, and the most polite imagination she joined an uncommon strength of judgment, and to the most refined sentiments a learned curiosity. Superior to the rest of her sex, without being solicitous to appear so,

* Jerom Fracastorius was born of a noble family at Verona in Italy, about the year 1483. He studied physic, until a few years before his death, when he devoted himself entirely to the study of polite learning, mathematics, astronomy, and cosmography. He died of an apoplexy in 1553, and was interred in the church of St. Euphemia at Verona, where in 1559, he had a statue erected to him by order of that city. His poetical works are much admired, the principal of which are his *Syphilis*; *Joseph* an epic poem in two books, but left unfinished at his death; and his *Alcon*, seu de cura canum venaticorum. See his life prefixed to his works; Joann. Imperialis museum historicum. pag 16. Les eloges des hommes savans, tirez de l'histoire de M. de Thou. Tom. i. pag. 189.

† A lake in the territories of Venice, now called *Lagodi Garda*.

she could talk of ornament and dress whenever there was occasion for it, and ask proper questions upon more important subjects. A natural negligence, an easy unaffectedness, embellished all she said. She had beauty enough to gain her consort many friends, and judicious enough not to shew any one a particular regard; and these accomplishments being seldom found united except in books and the imagination of authors, is the reason, I believe, that learning in ladies does not meet with so universal an applause from the world as their beauty.

When impertinent visitors gave us some respite from play, that relief and plague of society, we passed some part of the day in reading ancient and modern authors, contrary to the opinion of that monarch * who preferred old books like old friends. Our principal reading was poetry, as this seemed of all others most agreeable to the country from whence the genealogists of polite literature tell us it derived its original. But, however, that we might preserve a certain spirit of liberty, upon which all our conversation was grounded, we did not entirely exclude that sort of poetry which is formed expressly for the town, as satire, comedy, and epic. This spirit had a more particular influence upon our criticism, which regarded an Italian, a French, an ancient and a modern author, with an equal impartiality. The sober dignity and purity of the *Eneid*, the variety and perspicuity of *Orlando Furioso*, the noble finishing of the *Gierusalemme Liberata*, the justness, the philosophical spirit, and the

* Alphonfus the 10th king of *Arragon*, surnamed the Wise, who used to say, he desired little more than four *old* things, viz. *old* wood to burn, *old* wine to drink, *old* books to read, and *old* friends to live with. He began his reign in 1252, and died in 1284.

peculiar beauties of the *Henriade*, the invention of the *Mandragora* *, the characters of the *Misanthrope*, the sweetness of verse in † *Sannazarius*, and the happy negligence of *Chappelle*; all these we compared in such a manner, that we neither esteemed a verse the more harmonious for its antiquity, nor a thought less sublime or elegant from any difference of country. We interspersed our discourse with episodes and digressions, which the marchioness did not think herself less obliged to me for, than if I had given her an encomium upon her beauty.

In one of these digressions, I spoke of the force and advantages of English poetry, which gave her a strong inclination to be acquainted with it, imagining that a nation, to whom *Minerva* had lavished her favours in so profuse a manner, could not be destitute of those of *Apollo*.

As I desired nothing more than to give pleasure to a person who continually afforded so much to me, I was extremely sorry that I could trace her only a very low and imperfect idea of *Dryden's* harmonious copiousness, *Waller's* softness, *Prior's* various and easy stile, the lively wit and fire of *Rocheſter* and *Dorset*, the correct majesty of *Addison*, the strong and manly strokes of *Shakespeare*,

* *Mandragora* or *Mandragola*, an Italian comedy written by the famous *Nicolas Machiavel*

† *Actius Sincerus Sannazarius* was born at *Naples* of a noble family in 1488. He was secretary to *Ferdinand* king of *Naples*, who honoured him with a great share of his confidence and esteem. He was eminent for his Italian and Latin verses. He spent twenty years in correcting and polishing his poem *De Partu Virginis*; but his piscatory *Eclogues* in *Latin*, which he wrote when he was young, were preferred to all his other poetical writings. He was rewarded by the *Venetians* with a present of 600 crowns for his celebrated epigram,

Viderat Hadriacis Venetam, etc.

He died in 1530 of grief, because the prince of *Orange*, who was general of the imperial army, had demolished a tower belonging to his country-house. He lies interred near *Virgil's* tomb. See *Paulus Jovius* in *Elogiis*, etc.

and the astonishing sublimity of Milton. To speak of the merit of a poet, is the same thing as endeavouring to describe the beauty of a face, which can be judged of only by the sight; and to quote, even in its original language, only one particular passage separate from the rest, would be the same as shewing an eye, a lip, or a dimple of a face, of which we desire to see not single features, but the whole, whose beauty and symmetry are the result of innumerable charms. However it gave me a little consolation when I remembered, that, among some papers which I happened to bring with me into the country, I had Mr. Pope's Ode on St. Cecilia's day. None can be unacquainted with the name of this great author, without at the same time ignorant that there is any such thing as poetry in the *English* language. The next morning I carried this fine Ode with me into the grove dedicated to our poetical conversation, and now become the Parnassus of all nations. After having begged pardon of the *English* muses, I translated it as well as I could, and began to read. The marchioness listened to me with an attention that fine ladies seldom give themselves the trouble of. When I came to this passage —

*While in more lengthen'd notes and slow **

The deep majestic solemn organs blow;

she interrupted me, and could not enough admire the propriety of these *epithets*, which, added she, describe that instrument in such a manner that I really hear it play. I cannot tell whether you hear it too, but I think I may reasonably conclude it from a certain pleasure you shewed, perhaps, insensibly, in reading this passage to me. You

* Mentre con tarde ed allungate note
Il profondo, solenne, e maestoso
Organo soffia ———

are so well acquainted, Madam, with the most secret motions of my heart, that it is impossible for you to be deceived; and you commend a thing that certainly renders the image, which is the support of poetry, extremely lively and expressive. These sorts of *epithets* are the strokes that give life to the picture. A *white* hand, a *serene* brow, and *bright* eyes, are at best but the rough draught of it.

Now we are speaking of epithets, is not *the seven-fold Light*, which I read of some time ago, replied the marchioness, in an Ode made in honour of the philosophical lady* of Bologna, some Chinese hieroglyphic? at least it is so to me and many others whom I have desired to explain it. You mean, answered I,

—*The sevenfold Light*

*Whence ev'ry pleasing charm of colour springs,
And forms the gay variety of things †.*

If you knew the force of this epithet, you would see a Newtonian picture instead of a Chinese hieroglyphic, though perhaps a little too philosophical for poetry. What! answered she, interrupting me with an air of surprize, you understand this passage as well, as if it was the production of an English author. I am of opinion, Madam, answered I, that the verses of an Italian who has the honour to be a great admirer of you, are infinitely preferable to those of an unfortunate Briton, who has the unhappiness of being at so great a distance from you. I understand you, continued she, and I need not desire a better

* Laura Maria Katherina Barfi, a learned lady in Italy, who in 1732, at 19 years old, held a philosophical disputation at Bologna, upon which she was admitted to the degree of doctor in that university.

† O dell, aurata
Luce settemplice
I varioardenti, e misti almi colori,

encomiast than you, if it be true, that no one understands the sense of an author so well as himself. Come then, since you are the author of this piece, deliver me from the perplexity I am under about this *sevenfold* Light, and the rest of your Newtonian picture, which gives me great reason to believe, that in praising one lady, you have used your utmost endeavours that no other should understand your meaning. It is certainly that profound respect that I have for you, Madam, answered I, which has made you find me out. Afterwards, reflecting that it was impossible to give her in few words an explication of Sir Isaac Newton's optics to which these verses allude, a thing which she had not the least idea of, had not we better follow the example of the theatre, Madam, said I, where the play is generally at an end when the persons come to a knowledge of one another? And besides, we should finish Mr. Pope's Ode, which will certainly give you a far greater pleasure, than any comment upon mine. No, no, said she, we will finish that another time, and for the present we shall act contrary to the theatre, but without forgetting the catastrophe, or finding myself in as much ignorance as ever.

Being willing to give her some idea of the system to which these verses refer, and thinking that the Marchioness would for once be like other ladies, who are often desirous of seeming to understand what they are not supposed to have the least notion of, I told her as briefly as I could, that according to Sir Isaac Newton's opinion, or rather as the thing really is, every ray of light is composed of an infinite number of other rays, some of which are red, some orange and yellow colour, others green, some blue, some indigo, and others violet; and that from the composition of these seven colours in a direct ray from the sun arises the

white or rather golden colour of light: that if this direct ray from the sun is refracted by a certain glass called a prism, these rays of which it is composed, differing in colour, differ also in degrees of refrangibility.—I see, said the marchioness, interrupting me in a manner very different from what I expected, that your comment has more need of an explanation than perhaps the text itself. But this is my fault in not being able to understand your *refraction, different degrees of refrangibility*, and the like, which quite confound the idea I had begun to form. But pray explain yourself in such a manner that I may not have any farther reason to accuse you with obscurity, nor my own dulness with being the cause of it.

You will not be satisfied, answered I, unless I make you a comment at least as long as that of the Malmantile, which, I observed to you the other day, seemed to be dictated by the agreeable Mathanafius* who was formerly the Moliere of the commentators: at least, said she, Newton will enter more properly here than Micheli does there, whose discoveries are of no sort of service to illustrate this poem; and since all you said was spoke with an air of seriousness, and such confidence that you did not scruple saying, *according to Sir Isaac Newton's opinion, or rather as the thing really is*, you have made me extremely desirous of becoming a Newtonian. This, answered I, is a very ready method of propagating Sir Isaac Newton's philosophy and bringing it into fashion. Pemberton, Gravesand, and Dunch, the zealous propagators of this

* Monsieur d'e St. Hyacinthe, under the fictitious name of Dr. Mathanafius, published a piece intitled, *Chef d'Oeuvre d'un Inconnu avec des remarques*, in order to ridicule the impertinence of some critics and commentators. The *Malmantile* is an Italian piece wrote after the manner of this author.

system, would be very glad to give the care of it to you. But what will Mr. Pope say, shewing her the book which I had still in my hand, if you leave him in the beginning of this fine Ode, for a sudden fancy that you have taken to light and colours? Mr. Pope, answered she, cannot be offended at my leaving him for a philosopher, and such a philosopher as Sir Isaac Newton, one of his own countrymen too. Do not you know, said I smiling, that the poets look upon themselves as sacred, and when they have once got this enthusiasm into their heads, they regard neither country nor relations, but think themselves greater than any philosopher, even if he had discovered wherein consists the union of the soul and body? It is well for us, said she, that the poets have more modesty than to declare this in their writings.

It signified nothing for me to plead incapacity and many other excuses, which are made use of on the like occasions, and which occurred to me upon this. The marchioness insisted upon seeing my Newtonian picture as she called it. I begged she would at least have patience till evening, telling her that the night had always been the time consecrated to philosophical affairs; and that the most polite philosopher in France had made use of it in a circumstance resembling mine, and made no scruple of entertaining a fine lady with philosophical discourses in a wood at midnight. But we, Sir, replied the marchioness, ought to make use of the day, which is certainly more proper than the night for a discourse on light and colours. She spoke this with an air of authority that enforced her commands in the most amiable manner, and made it a pleasure to obey.

Thus I was absolutely obliged to begin, but the diffi-

culty was how to do it; for she had not the least notion of physics, which it was necessary to give her a general idea of, before I proceeded to a discourse upon light and colours on the Newtonian system. At last, after having again in vain reminded her of Mr. Pope, and other subjects that required less application and afforded greater pleasure, when the heat of the sun, which was now almost at his meridian, obliged us to retire into the house, I began after the following manner.

It is natural to suppose that after society was so well established among mankind, that some of them had nothing to do, which I look upon as the epocha of its perfection. These persons either from that curiosity, which we naturally have about those things that concern us least, or perhaps for fear of being charged with idleness by the rest, applied themselves to consider that variety of things of which this universe is composed, their differences and effects. It is probable too, that one of the first speculations that these idle people, who afterwards assumed the name of *philosophers*, employed themselves about, was concerning the nature of light, which is certainly the most beautiful and conspicuous object of our sight, and indeed the means by which we see every thing else. This consequently led them to the colours which this light depicts upon objects, and which diffuse such a variety and beauty on our world. Thus, I believe, that *Optics*, which is that part of natural philosophy that regards light and colours, and in general all natural philosophy, had their origin among men at the same time with their idleness: indeed it was of a latter date than some parts of morality and geometry, which were absolutely necessary in the earliest ages of the world, but contemporary to poetry, if

you will, and antecedent to metaphysics, which required a still greater vacation from business.

I am pleased, replied the marchioness, that poetry and natural philosophy have one common date; since for that reason you will not perhaps think this transition so strange, that we have made from one to the other upon my account. The transition, answered I, that our philosophers made from a slight knowledge of things to an ambition of unfolding nature and penetrating its effects, was much stronger. This, in the language of philosophy, is called making *systems*. This is just as if any one, after having had a cursory discourse with a subtle minister of state about good or bad weather, should attempt to write his character, and pretend that he had penetrated his most profound secrets. They should have begun with a very attentive examination of things, drawn from frequent observations and diligent experiments before they ventured upon the least system. They were to act, if possible, like those two antient philosophers; one* of whom, in order to write on the nature of bees, retired into a wood, that he might have the better opportunity of considering them; and the other† spent sixty years in making observations upon these insects. But the misfortune is, that experiments and observation require patience and time, and very often we are indebted to mere chance for the most useful and entertaining among them. On the other hand, men are always in haste to arrive at knowledge, or at least to have the appearance of it.

After this, the revolutions of states, the rude and uncultivated manners of the people, the temper of nations, and

* Philiscus. Vid. Plin N. H. L. xi. C. 9.

† Aristomachus. Id. ibid.

the profession of those, among whom philosophy had formerly flourished, did not a little retard its progress. From the Indians traditions which their priests kept to themselves with as much jealousy as they did their genealogies, and from the Egyptian temples, where it had long lain hid under mysteries and hieroglyphics, philosophy at length took its seat in the portico's and gardens of Greece, where it was very soon embellished, and corrupted with allegory, fables, and all the ornaments of eloquence. Imagination, which is the characteristic of the Grecian genius, prevented philosophy from taking any deep root, and indeed it was attempted to have been totally extirpated by the eloquence of a man, whose discourses were distinguished by a certain grave and elegant pleasantry, which made him master of the most powerful arts of persuasion, and who had been judged by the oracle the wisest among mortals. He asserted, that we have nothing to do with what is above us, and strove to reclaim our curiosity and studies from natural to moral objects; from the combinations of the universe, to the little chaos of human extravagancies, and from that rapture with which we are transported by the contemplation of vast and distant objects, to the melancholy consideration of our own emptiness. And this person, who, more destructive than Pandora, engaged mankind in a consideration of that train of evils which had issued from her fatal box, without giving them * any hopes of a cure, was had in the highest veneration, as the father of a new philosophy called *moral*, which is of all others the most treated of and the least understood.

* It is probable that the greater part of those, who are acquainted with the character of Socrates, will think our noble author has passed too severe a censure.

Philosophy after this, together with luxury, riches, and corruption, was transported from Asia to Rome. It could make but little progress among a people who cultivated hardly any other arts but those of pardoning the vanquished, and depressing the proud. In the first ages of christianity, philosophy lent its assistance to combat paganism, and after this was subdued, it raised so many civil wars and dissensions among those who by its assistance had triumphed over Jupiter and Olympus, that the ecclesiastical ship seemed in danger of perishing when it was hardly loosed from the port. To this fatal war of words succeeded that which the Barbarians raised against learning and the Roman empire, wherein both were equal sufferers; for it destroyed the one, and sunk the other, untill from the profound darkness, which afterwards followed, some sparks of antient knowledge were re-kindled among the Arabians. The doctrine of Aristotle revived, and being spread through the East, was gladly embraced by the monks, as it was the most suitable to their manner of life. How much pains and study are necessary to frame a right philosophy! It requires no less art and labour, than to make those fine silks which you ladies are adorned with. But the philosophy, in which the name of Aristotle supplied the place of reason, did not greatly disturb the monastic tranquillity. This philosopher who was banished * from Athens by the antient priests, was, but with some

* Aristotle retired from Athens, in order to avoid a process of irreligion which the Athenian priests carried on against him. The circumstances of this affair are unknown: some assert, that he was charged with impiety on account of a hymn which he had made in honour of his friend Hermius. This hymn is still extant, but there is not the least impiety discoverable in it; but his accusers urged that he had profaned divine songs by prostituting them to the honour of a mortal man. Aristotle, not thinking it safe to trust to the interpretation this little poem might meet with, retired very pri-

variety of fortune, received by ours; who, though they once condemned him as a * pernicious author, yet afterwards carried the zeal for him to such a height, as to believe him not ignorant even of those things which are above the reach of human reason. Religion at this time was more than ever united with philosophy, which could not fail to produce the utmost confusion in the one, and ignorance in the other, since both their nature and end are extremely different.

A chaos of vain and useless disputes, a chain of unintelligible definitions, a blind zeal for wrangling, and a still blinder devotion for Aristotle whom they called, by way of

vately to Chalcis, where he pleaded his cause at a distance by writing, which was the safest way he could take; for his accusers were a set of men who would never have let him been at rest. Others affirm that he was driven from Athens for the goodness of his morals. Some authors report, that this philosopher drowned himself in the Euripus, a narrow sea near Eubœa, because he could not find out the reason of its ebbing and flowing seven times a day. But the more received opinion is, that his very great application, in the study of this phenomenon, brought an illness upon him, which occasioned his death. See Bayle's life of Aristotle in the general dictionary, vol. II.

* The French, who took Constantinople about the 13th century, having brought the books of Aristotle into their own country, his doctrine began to be publickly taught in the university of Paris, and continued so for some time. But Arnaury a student of that university, having advanced several obnoxious opinions, and endeavoured to defend them from the principles of Aristotle, the physics and metaphysics of that philosopher were burnt by order of a council held at Paris in 1209, and the reading of them prohibited under pain of excommunication. This prohibition was confirmed about the year 1215, by the Pope's legate, who was employed to reform the university of Paris; but he allowed the logic of Aristotle to be taught. Gregory VII. renewed this prohibition in 1231, but with this addition, that he only forbid the reading of Aristotle's works till they should be corrected. In 1261, Simon the legate of the see of Rome in his reformation of the university confirmed the regulation of the year 1215, relating to Aristotle's writings without mentioning the correction of them. But in the reformation of the university in 1366, this philosopher's physics, as his other works, were allowed to be read. Vid. Father Rapin's comparison of Plato and Aristotle; Du Pin's Nouvelle bibl. etc.

distinction, *the philosopher*, or a second nature, and above all a certain jargon of indeterminate, obscure and hard expressions, either without any meaning, or confused, overspread, like a destroying deluge, the face of the whole earth, and for many ages usurped the pompous name of science. As among the Chinese he is esteemed the most learned, who can read and write more words and figures than the rest, so he was counted to have most learning amongst us, who, in a particular habit, could pronounce in certain places, and with certain gestures, and seemed to understand the greater number of expressions in this vain and pedantic jargon. The distinctions and answers might be as easily foreseen by any one who had a little examined their memoirs, as the turns of music in country scrapers, or the jingling of rhyme in bad poets. Such were the veils under which they hid, from the eyes of the world, that ignorance which very often they could not hide from themselves. The pride of schools was supported by the noise of empty words, and the tyranny of names. It was imagined that they really contended for truth, but these grayheaded children in reality amused themselves only in fighting with bubbles.

This obstinate veneration for the antients, which for a long while passed among the philosophers as hereditary from one generation to another, was the cause that the knowledge of physics made little or no progress till the last age. At length, among some few others, who were to fall as it were martyrs to reason, there appeared in Tuscany a person named * Galileo, who had the courage not

* Galileo was born at Florence in 1564. He was put into the inquisition for maintaining the diurnal motion of the earth, and asserting the sun and not the earth to be the center of the world. These propositions were condemned by the Inquisitors as false and heretical. He was not discharged till he had promised to renounce

not only to say, but what is worse, to demonstrate with the clearest evidence, that men, who had perhaps for sixty years been honoured with the title of doctors, or sat in the chair of philosophy, had taken very great pains all their life long to know nothing. All this boldness cost him dear; for to venture to make use of his reason was the same thing as reproaching them with the general abuse they had made of theirs; and to endeavour at the promotion of knowledge was as dangerous as an attempt to change the boundaries of antient Rome, which the Augurs took such a religious care in the preservation of. After such a course of ages, he shewed them what ought to have been done at first, and began to make a search into nature by observations and experiments, reducing himself to that ignorance which is useful for arriving to some knowledge at last.

I think it not improper to call this man the czar, Peter the Great, in natural philosophy: each of them had to do with a nation pretty near the same character. No one people ever used such endeavours for knowledge, as the Muscovites did to know nothing. They forbid all strangers to come into their country, and all the natives to go out of it, for fear they should introduce something new.

his opinions, and not to defend them either by word or writing, or insinuate them into the mind of any person. Upon his publishing his dialogues upon the two chief systems of the world, the Copernican and Ptolemaic in 1632. he was again cited before the holy office. The same year the congregation convened, and in his presence pronounced sentence against him and his book, committing him to the prison of the holy office during pleasure, and commanding him as a saving penance for three years to come and repeat once a week the seven penitential psalms, but reserving to themselves the power of moderating, changing, and taking away, altogether or in part, the above mentioned punishment and penance. He was discharged from his confinement, in 1634, but the impression of his dialogues of the system of the world was burnt at Rome. Vid. the general dictionary.

Thus was it with these philosophers, who, jealous of their tenets, renounced every experiment, and more certain demonstration of the moderns, rather than introduce any novelty or reformation into their own systems: but as force has generally more influence upon men than reason, the Czar compassed his designs sooner than Galileo, who was at the same time obstructed by another species of philosophers, who were by so much the more formidable as they too despised the antients, which now began to be the fashion, and asserted things in opposition to them of which every one had a clear and distinct idea. They introduced exactness and order in writing, which were then as uncommon as they are natural and necessary, and by means alone of certain motions and figures, which they knew how to give to bodies at proper times and on proper occasions, promised to unfold what seemed the most unexplicable in nature. You may easily imagine that the magnificent promises of these philosophers, which so agreeably flattered the ambition of the human mind, which Galileo's observations served rather to humble, joined to a certain simplicity that gave such an air of wonder to their systems, as it does to a well concerted romance, must naturally seduce many people, and form a sect. And it indeed had this effect; so that these moderns too began to have expositors, and followers as obstinate and zealous as those of the antients had been before; and these made themselves the more ridiculous by laughing at the same fault in others. But it was a melancholy thing to see an experiment sometimes offer itself, which had never before been known or thought on; and the finest and most artificial systems, which had perhaps cost their inventors whole months of labour and study, shamefully fall to the ground.

In order then to avoid these sorrowful reflections, said the marchioness, it is necessary for those, who would form a system in any thing, to be careful first to take notice of all that is observable in it, that it may not be exposed to the mercy and insults of experiments. This is exactly what the Newtonians say, answered I; and certainly, madam, you must have some secret intelligence with them to be so well informed of their sentiments. It would be ridiculous for a mechanic to take it in his head, to guess how the famous clock of Strasbourg is made within side, if he had not first acquainted himself with the outside, the manner in which it strikes, and those many other things it does besides telling the hour. Thus, say they, if we can ever hope to make systems that carry some appearance of being durable, it will be then only when by the means of experiments and observations we shall know all, that in terms of art is called *phenomenon*, which signifies the appearance of things, and the laws which result from these phenomena, and by which nature constantly performs all her operations. How then could Des Cartes, for example, who was the chief author of this enterprising sect of philosophers, make a rational system concerning *light* and *colours*, when he was entirely ignorant of so many of their qualities, which Sir Isaac Newton afterwards discovered by observations? How could he form the statue, when he had not the marble? This is the manner in which the rest of the philosophers of our time, and those learned societies, founded and maintained by the liberality of princes, or the genius of nations, proceed: they make observations and prepare materials for posterity to build systems upon, more fortunate in their duration, than those that preceded the present age. This profession indeed is not so pompous as

that of those who will build you a world in a twinkling of an eye; but on the other hand it has this advantage, that it is able to make good its promises, which is as great an obligation upon a philosopher, as a mistress.

I, who am a woman, replied the Marchioness, confess that I love those who have the courage to venture upon grand and difficult enterprises. Is not this the reason why we interest ourselves so much in the adventures of heroes? The courage of those philosophical heroes has something sublime and superior in it: if they do not attain to all they promise, must there not be given some indulgence to the imperfections of human nature? On the other hand, if, as you say, there cannot be any good systems, till all the phenomena are fully known, when shall we have them? They will happen as seldom with us, as the secular games anciently among the Romans: and I cannot flatter myself that I shall live long enough to see so much as one in my time. I must be contented then with those systems that we have, be they what they will. I believe, Madam, answered I, that no one could have more specious reasons to allege in favour of trifles. I should serve you right, if I put you on proving these reasons; but as I will act more mercifully with you, than you perhaps would with regard to me, since you have a mind that we should reason away that time, which might be better employed on pleasure, I will not make use of that right which these reasons of yours give me, to propose to you seriously the important questions, whether light be a substance, or an accident, or an act of the pellucid, as far as it is pellucid? Whether colours are the first configurations of matter, or a certain little flame that arises from bodies, whose parts are proportioned to our sight? I might gravely ask you too, that you may see how many things I spare you the trouble of

considering at once, whether light, or its spirit, be the soul that Plato places between nature and ideas, to connect the sensible and intellectual world? and whether it was for this reason that Plato represented the element of fire, which is the seat of light, under the figure of a pyramid, which in some measure agrees with that sublime and mystic triangle which is the symbol of the soul? idle enigmas of the learned ignorance of past ages! and who can tell but if you had fallen into other hands than mine, you might have been set a yawning with some gothic passages out of Dante? Or perhaps by this light, you would have been gradually conducted to divinity; at least you could not have got free from an explication of the mystic sense hid under the fable of Prometheus, who stole light from the sun to animate his statue.

I see, said the Marchioness, that philosophers are to be dealt with in a very circumspect manner, who know how to improve every thing to their own advantage. You act just like tyrants, who think they confer a great favour on any one, whom they have not injured. However, I am much obliged to you, for sparing me the trouble of hearing all these fine things, which, I confess, are quite above my understanding.

Let us see, answered I, whether you can understand the doctrines of some among the ancients who were more prudent and humane than the rest. These laboured to explain every thing by a vacuum, and the motion and figure of certain very little particles, which they called atoms, and from thence gave their schools the name of *atomists*, which was perhaps the most antient of all other sects, and lately tried by the splendor of eloquence to rise upon the ruins of the Aristotelian, in opposition to that of Des-

cartes. These philosophers asserted that the light of the sun, for example, was nothing but a perpetual and copious stream, of the very little particles, or atoms, which, flowing from the sun himself, spread themselves every way with an incredible velocity, and fill the immense aerial space; so that light is always followed by new light, and one ray is as it were impelled by a second. You may easily understand this by the similitude of a fountain.—I understand it mighty well, interrupted the Marchioness, without the fountain; but I am greatly afraid that these atomists of yours, by making so many particles continually proceed from the sun, will at last turn some fine day into midnight. Truly, answered I, that would be playing us a villainous trick, which no one would get any thing by, unless perhaps some few beauties, who would then always be seen by candle light: but do not fear it. Revolutions of this importance require more time to be brought about, than the revolution of a monarchy. And besides, these atomists give us so great a security that it would be a shame to dread it. For, in the first place, they tell us, that the rarity and incredible smallness of these little particles that proceed from the sun, which sun they make to be of a dense and close matter as you will see hereafter, in a very long course of years will produce only a very little diminution in his light. And to make you still more secure, this may be confirmed by the example of a little grain of colour, which is sufficient to tinge a very great quantity of water. An example, drawn from odorous bodies, may serve to shew you how very much the parts of matter may be subtilised; as for instance, a grain of musk, which, though it continually emits a prodigious quantity of particles, yielding a perfume so strong and quick, that at a certain

distance it is able to stupify serpents of a monstrous size, and quite deprive them of motion, yet in a considerable time its weight is but very little diminished. And amber-grease, in the same manner, for a long while loses hardly any thing of its agreeable scent. From light's passing through the densest bodies, such as diamonds, and gold when it is beaten into thin plates, we must necessarily infer, that the particles of light are extremely subtile. All this is mighty well, replied the Marchioness; but that such a quantity of light should continually proceed from the sun, as is sufficient to fill and illuminate the whole world, puts me into terrible apprehensions, notwithstanding all your fine examples of musk, amber grease, and diamonds.

Have not you some inclination, answered I, to the learned melancholy of the inhabitants of Dean Swift's flying island? who in the most poetical allegories has given us the most philosophical satire upon mankind. This island, which in the language of the country is called Laputa, as it is different from all that have hitherto been discovered by our voyagers, so it is inhabited by a very singular species of men: always abstracted and immersed in the profoundest speculations, they give themselves up to spleen and the mathematics, so that they have always need of a *Flapper*, who, by striking them from time to time with a bladder, may bring them back to the world below; their knowledge fills them with those continual fears and disquietudes which the vulgar by a happy privilege of their ignorance are quite free from. They are afraid that a comet, by approaching a little too near the earth, may in an instant reduce us to ashes; or, that the sun one day or other will swallow us up; or, that this immense source of light and

heat will at length be exhausted and leave us involved in a profound and eternal night. May not your fears, Madam, be said a little to resemble those of the Laputian school?

As to the *flapper*, answered she, I have nothing to do with that, especially when I am with you. But do you not think that there is some reason for me to be frightened at the terrible threatening of a perpetual night? Ought you not rather to think yourself obliged to me for interesting myself so much in the cause of *light*, which you have made your heroine? It would be quite shameful that I should shew more regard and concern for it, than yourself. You shall see, Madam, answered I, that these atomists have taken care to secure your repose, and preserve what you shew such a regard for. They will find you a method to recruit the sun with that facility which a philosopher is master of, who knows how to make all nature subservient to his schemes. They will make the seeds of light and heat, which are diffused through the universe, continually return back again into the sun, in order to repair his losses. They will place something round him with which he is sustained and restored just as a lamp is fed by oil or some other matter. We will call certain systems to our assistance which will lend us comets that from time to time shall fall into the sun and yield him fresh supplies: and if this be not sufficient, we will have recourse to some philosopher, who may find means to make a star fall into him. And if you have not confidence enough in human systems, we will call a celestial one to our aid, revealed to Adam by an angel in Milton, who assures us, that the sun draws his aliment from humid exhalations, and in a regular manner takes his supper every night with the ocean. Will you have any more? No, no, said she, the

one half of these things is sufficient to dissipate the fears of a Laputian himself. And I hope there will be no need at present to trouble any philosopher, much less a superior Being.

I wish, answered I, that your fears may never extend to any thing farther than philosophy, and that your beauty, as it has many other qualities in common with the sun, may have a common duration with him. But I am extremely glad that since I have delivered you an opinion which at first sight gave occasion to your fear, it is capable too of dissipating that fear: as you are so very subject to be frightened at every trifle, I do not know what would have happened, if I had told you the opinion of a famous antient, who affirmed the sun to be a mirror formed of a substance resembling the most polished chrystal, that sends and reflects the light to us, which is transmitted to all parts of the universe, and there unites. What hopes should we have of finding proper materials above, to repolish this mirror, if it should ever happen to be sullied and grow dim? Let him, replied the Marchioness, who made the sun a mirror, contrive how to repolish it when it shall want it, I had rather imagine it to be the soul of the world, and to be itself the source of light. You should have added, that it is the source of colours too, answered I, since without light these entirely vanish and are no more. Say rather, replied the Marchioness, that they are no longer visible. Will you tell me that an hour after sun-set, there are no colours in this picture? I should be glad to hear you prove to me that the picture too is vanished for the same reason, because it is no longer visible. The picture, answered I, and the canvas still remain, and upon it certain dispositions in the figure and texture of those atoms,

of which the chalks that are made use of in the painting are compos'd. And these dispositions, at the approach of light, will again make the colours mezzotintos and chiaro oscuros, appear upon the canvas, and restore to your sight a commanding beauty, a flight of pillars, a verdant meadow, or the opening blushes of the morning. In the dark all these objects vanish, as they are the result of a combination of those dispositions and light together. I might allege the authority of Virgil upon this occasion, who informs us, that objects lose their colours at the approach of night. Lucretius*, who, in the most elegant verses, has given us a body of this atomic philosophy, makes us apprehend most terrible consequences from a supposition that bodies and their principles are endued with colour. For, says he,

*Seeds are colourless without a dye.
For either this cannot to seeds agree;
Or seeds are not immortal all and free
From change, and therefore things may fall to nought.*

CREECH.

You give me consequences and verses, said the Marchioness, when I want evidence and explications. Descartes, answered I, will afford you enough of this, who has discuss'd this matter much more fully than Lucretius. His principles are different, but in this point he agrees with the atomists. But you want systems, and I must satisfy you: you shall see the most daring products of imagination, which have for some time deceived those, who assumed the pompous title of searchers after truth. The illusion is at length vanished, and philosophers are grown more

* Proinde colore cave, &c.

Lucret.

cautious and difficult, and examine one another with more violence than the Egyptians did their dead before they would allow them the honour of sepulture. Come, said the Marchionefs, explain me this system of Descartes. I shall not be so difficult as not to receive pleasure from it, even if it be such a one as you make me expect. It is pity, Madam, answered I, but that every thing should from this time be proposed to you under the form of a philosophical system.

Suppose to yourself, that all the matter, of which this whole world is composed, was from the beginning divided into exceeding small and equal particles, of a figure nearly resembling a dye. Suppose too, that some of these particles turn round one point, and some another, and that at the same time they all turn round themselves like a wheel, which, while it is moving to any particular spot, makes many revolutions about its self. The points about which these particles turn are the stars, the most luminous and shining points in the universe, and which will help you to conceive it full of *vortices*, for this is the name that is given to any mass of matter that is whirled round a point or common centre, just like the circles of water in a river, or the dust that flies when it is agitated by the wind. I believe you will not scruple to grant the sun a *vortex* of his own upon my assertion, since he is not at all inferior to any of the stars. If you desire it, answered the Marchionefs, I will go farther, and allow him the largest and most magnificent *vortex* in the world. For I think he highly deserves it, to whom we have so many obligations. Philosophy, answered I, is less interested, and has no more partiality for the sun, than for the least star in the milky way. It is sufficient if you grant the sun a *vortex*, be it

what it will. From this *vortex*, you shall see the sun himself arise; for hitherto I have supposed him and the stars to exist, the better to assist your imagination; and with the sun, all the charms of *light* and *colour*, and I know not what besides. In short, it is like an enchanted palace, where you have only need to ask what you want, and it will appear in an instant.

What I have granted you is so little, replied the Marchioness, that I cannot flatter myself with the hopes of so great a happiness as you flatter me. The mathematicians, answered I, are said to resemble lovers. If what you grant them at first be ever so little, they know how to make so good an advantage of it, as to lead you insensibly farther than you ever imagined. Now you are to consider that this philosopher, to whom you have granted what you think so slight a concession, was a mathematician. I have as little skill in the artifices of love, said the Marchioness, as in those of philosophy and mathematics. But it is inconceivable to me that any thing reasonable can be produced by these *vortices*, which after all are nothing but collections of extremely small particles, that keep whirling round a point at the same time that each of them turns round itself. They may whirl on for ever, and I believe that will be the chief of their business. Who would ever have imagined, answered I, that the accidental meeting of a hero and heroine in a romance, and a certain *Je ne sçai quoi*, that he discovers in her, could have supplied matter for twenty volumes? and yet there are many instances of this, perhaps too many, in a nation very near our own. And without giving the heroes any trouble in this affair; what an infinite number of things might there be produced from that *Je ne sçai quoi*, that every one sees

in you? — Let us see at present, said the marchioness, what Descartes' *vortices* will produce; for after these twenty volumes, I shall begin to think every thing possible.

These particles then, continued I, in the figure of a dye, which you now begin to have a better opinion of, whirling in this manner round themselves, must make terrible collisions, and, consequently, break the angles or points of each; which deprive them of a power of turning freely round themselves. You know, Madam, that, if any thing be taken away from the corners of a dye, it will grow round, and in proportion as the angles of what remains of the dye keep successively diminishing, it will gradually approach still nearer to the shape of a ball. And this you are to believe was the case with these particles, which by continually striking against one another, were at length changed from their first figure of a dye, to that of so many little balls or globules. The matter which arose from the shavings of these angles, and which by its continual collision must necessarily be reduced into very small and volatile particles, did not remain idle, but had its proper office. It immediately declared open war against the vacuum of the atomists, and threatened to destroy and banish it from the universe, wherever it was to be found. The first undertaking of this matter was to fill up those little voids which otherwise would have remained between the globules; for though they touched one another, yet there must have been some empty spaces between them arising from the nature of a globular figure. But without the assistance of this *matter*, there would have remained a much more considerable void in the centre of the *vortex*. The globules were reduced to a much smaller

size than they were at first; and were proportionably removed from the centre, by a law common to all bodies moving in a circle; which recide as far as they possibly can from that point about which they turn. This matter then run into the midst of the *vortex* in order to fill the centre of it, and began itself to turn round together with the globules, and animate the rest of the *vortex*. This subtile and volatile substance, which is called the *matter of the first element*, or the *subtile matter*, forms nothing less than the sun and stars in the centre of the *vortices*; as the globules that turn round them, and which are called the *matter of the second element*, furnish matter for the heavens; and though the CARTESIANS have deprived it of that transparency and adamantine solidity that formerly rendered it so venerable among the antients, they have taken care however to atone for this injury, by making it the original of light, and by this means it has gained more than it lost.

What, cried the marchioness, are we got already to the origin of light? Your heroes and their twenty volumes have made a very bad use of their time, compared with us. If you give a farther attention, answered I, you will find they have made a much worse use of it, even than you believe. The system of Des Cartes presents you a scene, such as, I believe, you never beheld in the finest and most splended opera. The whole extent of the universe is sown and filled with innumerable *vortices* joined to one another of different size and figure, but all of them nearly round. These keep each other in a mutual equilibrium by their reciprocal pressure. In the midst of every one of these *vortices* is a star or a sun, that is to say, a large ball of *subtile matter* that strives to dilate itself, and presses the *vortex* all round. This pressure of the *subtile* communicated to the *globular matter*, or that of the second

element, gives birth to *light* according to the opinion of Des Cartes. The different bigness of the star, and much more its distance from us, cause the light of it to appear more or less lively to our sight: and hence it is that the splendor of the sun in whose *vortex* we are

— *with superior blaze*

Dims the pale lustre of the starry rays.

It is believed that Syrius, though his distance from us be more than two millions of millions of English miles, according to the calculation of a celebrated mathematician, is yet the nearest star that we have; because it appears larger than any of the rest, and its lively and sparkling light makes the longest resistance against the dazzling splendor of the sun.

I suppose, said the Marchioness, that out of partiality to your Syrius, you omit that star which the peasants call Diana, and the poets the harbinger of the rising day, and to whom, comparing earthly with heavenly things, they give the same honours as to Aurora. You must take care, answered I, not to confound two things together, which are very different from each other, as a body that is luminous in itself, and one that derives all its splendor from another; or in other words, a sun and a planet. It is true, that all the planets, as Venus, which in the language of astronomy is the same as your Diana, Mercury, Mars, Jupiter, Saturn, and our earth itself, were antiently so many suns, and may, perhaps, for who can penetrate into the secrets of futurity? hereafter be again restored to that honour. I have not yet mentioned to you another species of matter which is called the *matter of the third element*, and which has occasioned the greatest and most remarkable revolutions that are left upon record in the annals of the Cartesian philosophy, Among the particles of that

subtile matter of which the sun is composed, there are some that by their rugged and irregular figure unite and cling together, and by these means form masses that are sometimes bigger than our earth. These masses are driven away from the sun, and repelled to his superficies. The pressure that communicates itself from the *subtile* to the *globular matter*, or in other words, the *light* is interrupted in that part of the sun's superficies where these masses are placed, and from hence they appear to us as spots, which, turning round with the sun, eclipse part of his splendor and glory. Flattery perhaps made certain courtly astronomers take these spots for little planets, that get betwixt the sun and us, and made use of them to transport the families of those princes to heaven, from whom they expected some little pension on earth in exchange for the investiture of a thousand planets which they with great confidence promised them. Philosophical politeness transformed these masses into patches upon the sun's face; if you are better pleased with the idea under which they were represented to the queen of Prussia by the famous Mr. Leibnitz, who thought that philosophical terms should be softened for the ear of queens. The thing is too serious to bear a jest, said the Marchioness; patches as big as the earth might quite demolish a face.

Hitherto, continued I, our sun has been lucky enough to escape this misfortune. The motion and agitation of the *subtile matter* breaks and dissipates these masses as fast as they are formed. There once appeared one of these spots, which darkened the fifth part of the sun's disk. This was a most enormous and terrible bigness, enough to make astronomers tremble, and the whole world melancholy. The sun at last disengaged himself, and got the better of it, so there is now no reason to fear any such unlucky ac-

cident; but all the other suns were not born under such favourable circumstances. There are certain stars which are considerably diminished, so that what has formerly been placed by astronomers among those of the second magnitude, is now scarce worthy of being reckoned among those of the sixth. This must be ascribed to these spots which by length of time are so increased, as to form a sort of crust almost over the whole star, and consequently weaken its light.

On the other hand, said the Marchioness, might not certain stars arrive to a greater magnitude, if the agitation of the *subtile matter* was strong enough to dissipate part of their crust? You are thoroughly possessed, Madam, answered I, with the spirit of Cartesianism: this sect places its glory in conjectures, and you have made a very good one. But what a terrible desolation would it make in the poor star, if this crust should entirely cover it, as it too often happens, and should be strong enough to resist the force of the *subtile matter* that strives to break and dissipate it! When this is the case, we may bid farewell to the sun or star which has lost that place of honour which it before held in the universe. Its light is suffocated by the crust, and from a luminous and splendid body, it becomes dark and cold. The force of its *vortex* is considerably weakened as it arose from the *subtile matter*, which has now no communication with the globular. The *equilibrium* is broke, and consequently its *vortex* destroyed. Some one of the neighbouring stars carries it away with it, and now become a planet, it is forced to whirl round at the mercy of the most powerful. These are the most remarkable metamorphoses that can possibly happen, and to which our metaphorical suns here below are no less subject. When these begin to lose their lustre and have nothing left to

feed that passion which so agreeably flatters the pride of the fair sex, and which ought to be the subject of your philosophy, they are carried away and become slaves to another, which for their consolation they call virtue. Our fallen suns, answered she, have at least the advantage in this, that they acquire a fine name, and under the shelter of that they with great authority condemn what is no longer in their power to practise, and in some measure recover their lost empire. But what consolation is there for a miserable sun above, when it is enveloped with a crust, and changed to a planet? The consolation, answered I, of not having an odious and imaginary empire after having been possessed of an amiable and real one; the consolation, in short, of not growing like an old *Sybile* after having resembled one.

This miserable metamorphosis of a sun to a planet, accompanied however with some degree of consolation, is probably what happened to a fine star which we have entirely lost in the constellation of Cassiopeia; and this too, according to the Cartesian system, was the fate of our earth, which was once empress of an extensive *vortex* crowned with light, and one of the brightest eyes of heaven; but at length enveloped with a deformed crust, unhappily lost its power and splendor, and was carried away by the immense *vortex* of the sun, as a straw in a river by the impetuosity of a whirlpool. In the same manner, the other planets that revolve about him, Jupiter, Saturn, Mercury, Mars, Venus, fell victims to his superior power; nor could even the comets escape, though these are planets of a peculiar nature which keep rambling from one *vortex* to another, and like certain people among us here below, rove from one country and government to another. And these

vortices are the grand machine invented chiefly by Des Cartes, to guide the planetary dance round the sun.

Is the earth then, replied the Marchioness, after a short pause, like the other planets obliged to dance round the sun? And do all the mighty preparations, you made with *your matter of the third element*, amount only to this? The earth, answered I, does not need that concern which you shew for her degradation from a sun to the inferior rank of a planet; since by this means she was destined to give birth to you, who are but another name for the most charming thing, that all the *vortices* of the universe put together could ever have produced. Is not this a sufficient compensation for her loss? If it was in the power of gallantry, answered the Marchioness, to make her amends, yours would certainly do it. But what can ever free her from the disgrace of being obliged among the croud of other planets to whirl round the sun like a straw, agitated by the caprice of a whirl-pool? I am sensible that you philosophers look upon the earth with great indifference, and suffer it to turn round without regret; but for my part—Let it whirl round for this time, answered I, upon the word of Des Cartes. Hereafter if you have a mind to be convinced with pleasure, we will read M. Fontenelle's dialogues upon the plurality of worlds. There you will see a Marchioness, who exactly resembles you in every accomplishment of mind, and whom you have nothing to envy but her philosopher. At present you are to look upon the earth only as a composition of the *matter of the third element*, which renders it opaque, and as a body which no longer shines by its own light; and by this means I believe you will be pretty indifferent towards it. A glowworm, one of those reptiles that glitter by night in the country, is

much more worthy your attention; whatever is not luminous is nothing to us.

You have seen, continued I, what sort of a thing light is: you see too how the sun may continually supply so great a quantity of light as he does, without any expence to himself, which is what gave you such terrible apprehensions in the atomic system. He has nothing to do but to press the globular matter, and this pressure costs him nothing of his own, and since it is communicated on all sides, we are to conclude that he is luminous quite round. The light, according to Des Cartes, is but a moment in progress from the sun to us notwithstanding the distance of a million of miles. The globules of the second element are continued from the sun to the earth, like so many strings of beads, and touch one another. In the instant that the first in the string moves, or endeavours to move, it must also endeavour to move the last. Just as a pole, though ever so long, in the moment that one end moves, the other moves also.

The meaning of all this is, answered the Marchioness, that by means of these *vortices* philosophers may make and give a reason for every thing. In a moment's time we have produced the sun, stars, planets, comets, the earth and light. I suppose we shall form colours with the same facility. Nothing more easy to Des Cartes, I replied. As motion or a tendency to motion in the celestial matter, raises in us the sensation of light, so the different motions of this matter excite in us the perception of different colours, which are nothing but certain modes in which bodies receive light, and afterwards transmit it to our eye. These modes consist in the increase or diminution of that motion, by which the globules of light naturally turn

round themselves, and which is called the motion of rotation. Thus those bodies, whose superficies is disposed in such a manner as considerably to augment this motion of rotation in the globules of light which fall upon them, and are thence transmitted to us, appear to our sight red: those which increase the motion somewhat less, appear yellow: those, which considerably diminish it, appear blue, and those which diminish it in such a manner that these globules turn round slower than usual, appear green; and to conclude, those bodies, that transmit a great number of globules of light without altering their motion, appear to us white, and those seem black, which extinguish them, and as it were absorb the light. Here then you have the origin of colours, do you desire any thing more? It is only speaking; the *vortices* are as useful to Des Cartes as the cacao-tree to the Indians, which supplies them with all they want.

No, no, said the Marchioness, let us at present confine ourselves to colours: I need only increase or diminish the motion of rotation, in the globules of light, in order to form the shades of a fine silk, and variegate the parterre of a garden with the different beauties of hyacinths, anemones and violets, in short, to diversify the face of nature just as I please. Rather, said I, if this increase or diminution should give you any trouble, you need only suppose the globules of light to be entirely deprived of all rotation, which we will grant them only in the very action of variegating your silk or parterre, or in other words, in being repelled from the bodies upon which they fall. You may freely choose which of these methods suits you best. Each of them will equally serve your purpose. Des Cartes, seems to have had this too in common with the phy-

ficians, that he thought it unworthy his fruitful imagination to confine himself to one single method of making his designs succeed. Notwithstanding your malicious insinuation, replied the Marchioness, I think myself much obliged to Des Cartes for this copiousness. I dare say it will not fail him in explaining how it comes to pass that one body should give the globules of light a certain rotation, and another body a different one. You are not confined here neither, answered I, but have free liberty of choosing what method you like best for the explanation of the thing in question, either different figures of those particles of which the superficies of bodies are composed; or their different dispositions, their different inclination towards each other, or their being more or less smooth, and a thousand other things that you may imagine to yourself. By these means will your dextrous philosopher compose not only the finery of silks, and the variegated beauties of a garden, but all the elegance of a Paul Veronese or the delicacy of Titian; and hence too arises that lively bloom on your complexion, which perhaps not all the art of Paul and Titian could ever have imitated. I should not have thought, answered she, that the colouring of my cheeks would ever have entered into the Cartesian system. It enters, answered I, into other systems more generally understood, and of somewhat more importance than those of philosophy. But even these must receive great honour from the explication of so beautiful a phenomenon.

I protest, said the Marchioness, that this great plenty of causes, and above all the simplicity that reigns throughout this system, quite charms me, not to say any thing of those difficulties which it removes in all the rest. I should be glad to see how any other woman in my place would

guard against it. I am too well acquainted with the language of ladies, answered I, not to believe you already conquered. You have not sufficiently closed your ears to the song of this philosophical syren, nor guarded your heart against the alluring pleasures in the luxurious garden of this Cartesian enchantress. But you have forgot that yourself at first condemned this precipitation in building systems, which cannot afterwards bear up against the obstinacy of observers. Hypotheses, or imaginary systems cannot long resist the force of experiments, which are justly called by a man, who carried them farther than perhaps any one that may follow him, natural revelations. A liar, even if he was as ingenious as he in Corneille's comedy, will at last be found out. I had no notion, said she, that so many things could have been produced from so little a matter, as these whirling particles, and I think upon this account a little precipitation might be excused, and all this moralizing laid aside. I am extremely fond of the Chinese, because I am told they effect whatever they take in hand, with much fewer instruments and less apparatus than we do. And I think French music much preferable to ours, because by a few simple and plain notes it touches the heart, and moves the passions. Whereas ours, with all its divisions, fugues and shakes, leaves us for the most part in a tedious and stupid tranquillity. Those, who for every little thing make use of such great machines, put me in mind of the dictators antiently elected at Rome, with the utmost solemnity, and who never omitted choosing a master of horse for no other end, than to fix a nail in the capitol. You may add, said I, since you seek for examples illustriously ridiculous, those kings of Persia, who never eat, walk, or go into the seraglio, till an astro-

loger, after many observations and calculations, has assured them, that it is a lucky time to undertake one or other of these important enterprizes. If we had been in Persia, how many astrologers, how many calculations, must there have been employed before you could have been made a philosopher! which I take to be a thing of much greater importance, than the walk of a king. I am afraid, answered she, that before the astrologer had finished his calculations, my inclination for philosophy would have left me. But thanks to my good fortune, that I was born in a country, where if we have a mind to walk or hold philosophical discourses, we may do either without giving the stars or the sky any trouble about it. You ought rather to thank your good fortune, Madam, answered I, for being born in a country where your charms are not like those of the eastern beauties, confined to the narrow limits of a seraglio.

With these reflections of yours, said the Marchioness, you will make me lose sight of our colours, whose variety charms me the more, because the production of them cost me so little trouble. But how shall we produce those various colours which appear in looking through a certain glass which I once saw placed over-against a window? perhaps you have some other sort of motion to produce these colours which only appear to be in objects, when they are looked upon through one of these glasses. You may form these, answered I, in the very same manner as the first. You need only make the globules of light that pass through the glass you mentioned, which is called a *prism*, turn round according to those rules you have already learnt, and according as the variety of colours which it produces require. As to that distinction, which you seem

to put upon those colours which are really in bodies, and those which are so only in appearance, Des Cartes will not grant it you; for he, as well as the atomists, as you may remember, asserts, that there are absolutely no colours in bodies, and that they only appear to be so. Thus for instance, betwixt the red on your cheeks, and that in the rainbow, or *prism*, there is no sort of difference, only perhaps it would be more pleasant to make observations on one than the other. But after all, they are of the same nature, and only apparent. Do you think, continued I, laughing, that so many poets would have compared fine ladies to the rainbow, if there had not been some resemblance in their colour? as, for example, one of the greatest philosophers in our time has done in those sublime verses, where he is describing some beauty who perhaps resembled you.

* *Tale in somma ne gia qual di rubini
E d'or ricca, e di gemme e d'ostro adorno
Sorger veggiam la matutina aurora.
O qual sul variato e lucid arco
Apparir suol dopo nembofa pioggia
Di taumante la figlia; allorchè, i venti venti
Si stan sospesi a vagheggiarla e intanto
L' infano mar depon l'ira, e s'achera.*

You see, said I, that one of the most splended and pompous similes, that the poets have in their whole collection, would have been guilty of too essential an error.

Seriously, answered the Marchioness, I always thought that the colour on my cheeks, whatever it be, was really

* As our author does not mention where he had these verses, I would not venture to translate them from the Italian, since I am not certain, whether they were not originally written in English.

there, and that the prism or the rainbow were only in appearance; pray explain this paradox to me, which, to say truth, I am very much perplexed with; and deliver me from the uneasiness I cannot help feeling on your comparing me to the rainbow, notwithstanding you made me a great compliment by this fine simile. This, said I, is reducing things to that simplicity you seemed so fond of, by taking away the distinction which you put between real and apparent colours. But the interest you have in this distinction, and your self-love, that makes you tremble at the thoughts of losing your roses and lilies, to speak in the pastoral style, has at present got the better of your love of simplicity. I will engage there are many ladies who would have the same scruples: but after all, you cannot with honour adopt a system without being willing to admit the consequences. We have before said, that there is in bodies only a certain disposition and texture of parts, and in the globules of light a certain rotation which these parts give them. These globules in a certain manner tickling and shaking the nerves of the *retina*, which is a very thin membrane at the bottom of the eye, give us the idea of some colour, which we by the help of our imagination refer to the body from whence those globules of light are derived to us. But I think we are called to dinner, and it is time for us to see what taste our imagination will help us to give the soup. Our imagination, replied the Marchioness! I do not know whether he, who has laboured these three hours to give it a real taste, will be very well pleased with you philosophical gentlemen, who would reduce every thing to mere appearance. I dare say, answered I, that he will give himself very little trouble about such a trifle as a philoso-

phical opinion. But however, if he did, he must bear it; for as bodies are in reality without colour, so they are likewise without taste, smell, sound, heat, cold, and even when they appear most luminous, without light.

The Marchioness was very desirous that I should explain this paradox more fully: but I assured her, that if we stayed till the soup wanted heating again, not the finest and most simple explications in the world would help our imagination to give it a good taste. She was fully convinced of this truth, and we ended our discourse in the manner of Homer's gods, who after their consultations are sure never to forget their ambrosia.

D I A L O G U E II.

That qualities, such as light, colours, and the like, are not really in bodies. Metaphysical doubts concerning our sensations of them. Explication of the general principles of optics.

ALL the while we were at dinner, the Marchioness entertained herself with making the globules of light turn round, sometimes one way, sometimes another, as the different colours of the objects before us required, and looked upon herself, as she said, to be the empress and arbitratress of nature, since she was possessed of materials to diversify it as many ways as she pleased. As soon as dinner was over, and we had returned into the garden, I am ready, said she, to deprive the soup of all taste, and willingly renounce every colour, even what I had the greatest fondness for. In short, I will be quite a Cartesian, provided you can furnish me with good reasons. These globules, it is true, lead me to strange consequences, but perhaps they may furnish me with some expedient to evade them. You treat philosophy, answered I, as attorneys do the law. But there is no expedient that will hold good at the severe tribunal of reason. Not all the monarchs in the universe, nor all the beauties which are far more powerful, can influence the impartial judgment of philosophy, nor induce it to interpret the least text in their favour. This is a trial, a mortification that Des Cartes will make you undergo in your novitiate of philosophy. But are

you terrified at so small a hardship as this? Take courage and fear nothing; you will at last add to the pleasure you receive from your senses, that of contending with them, and giving them no credit.

Hitherto, said the Marchioness, I have only the mortification of seeing that we are under a perpetual delusion, since, if what you say be true, things appear to us very different from what they really are. Bodies appear to us of a certain colour, whereas there is really nothing else in them but a certain disposition of parts. They seem to us to be hot, cold, and yet they are possessed of none of these qualities. Really I cannot help thinking, that we are in a very strange condition. It is certainly very strange, answered I. Our knowledge can make but very little progress, unless it be conducted by the senses. They continually make us believe things, which a more refined sense, or our reason, afterwards contradicts. You think, for instance, that your hands, which have been the subject of so many fine verses, are smooth and polished; and possibly might be greatly offended, if any one should dare to dispute them this quality. And yet if you were to look upon them through a microscope, you would be surprized to see a great number of pores that separate the texture of them, and to find that they are covered with scales like those of a fish. You would discover in them cavities, promontories; vallies and hills, for the abode of a nation of little animals, who perhaps spend their life there. And to increase your wonder, you would be presented with the sight of rivers and seas. In short you would not know them again, and you would be obliged to confess that they are very different from those which your poets describe. Nature, said the Marchioness, has done us a great favour in not making

our senses too refined. It would be very bad for us, if our touch was exquisite enough to feel all that the microscope discovers to our sight. We should certainly be extremely unhappy, answered I, if our sensations were so perfect, that in handling the smoothest surface, our touch should fail us at every pore, and every little eminence should make us shudder. It is to the silence of our reason, and the want of more refined senses, that we owe our perceptions of pleasure. And he gave a very just definition of our happiness, who affirmed, that the most tranquil possession of pleasure consists in our being agreeably deceived.

It must be confessed, replied the Marchioness, that our sex is greatly obliged to the complaisance of philosophers, who, notwithstanding they are so well acquainted with the nature of our superficialities, are so genteel as to behave towards us like the rest of mankind. But if I had a mind to please any ignorant person, the very first thing I would do, should be to forbid him the holding any correspondence with those gentlemen who deal in microscopes; for these might do me a very great prejudice. Not all the microscopes nor all the philosophy in the world, answered I, could ever hinder your appearing agreeable to the naked eye, and even a Cleopatra might be contented with this. Virgil makes Corydon warn his Alexis not to confide in his beauteous colour. But I may freely give you leave to confide in your hands.

As our senses are not microscopical, so neither are our hearts philosophical. It would be very bad for us, if our pleasure was in the hands of philosophers, and if beauty, in order to prove its existence, must stand out against all the experiments of a naturalist. This is just as if the chasti-

ty of a lady should depend upon the ill-grounded suspicion, and diligent enquiry of a jealous husband. These two kinds of men have this in common, that they both equally tend to destroy the most valuable things in the world.

But philosophers, said the Marchioness, destroy without mercy; for they can leave but very little else to bodies, after they have deprived them of colour, taste, and those many other qualities which they have taken from them. They leave them, answered I, in possession of extension, that is, length, breadth, and depth; impenetrability, motion, figure, and all the fine things that mathematicians and mechanics deduce from these qualities, upon which I could produce you so many formidable volumes, that all which has been written upon the *Crusca*, would seem, compared to these, no more than a king's declaration of love. Do not you think it enough for bodies that they are no more than bodies? Besides, what philosophers do with regard to those qualities we were speaking of, is not properly a destruction: they take nothing away from bodies, but what was falsely applied to them, and what they had unjustly possessed; and restore those qualities to us, to whom they rightly and properly belong. Prescription has at present no influence on philosophy, as it formerly had. If a lover, for example, should say, that there was hope in a certain favourable glance, which had darted on him through a fan, what harm would a philosopher do, who, without destroying either the hope or the glance, should tell him that there was nothing in the glance, but a particular motion of the eye, caused by certain muscles, either from a principle of pity, or if we would trace the thing to its original, coquetry: but that the hope was entirely of himself, and excited by the means of that

glance. Just in the same manner, when we are pricked with a needle, the pain is entirely in our selves; and there is nothing in the needle but a motion by which it disjoins and lacerates the fibres of our body: this separation is the cause that we feel pain. In short, bodies are only matter, and consequently can have no properties but what depend on matter; and these the Cartesians have confined to extension, mutual impenetrability, diversity of figure, and a different disposition of parts. And these are sufficient to give bodies a power of exciting different ideas in us, as those of light, colours, taste, and the like. It is not necessary, for instance, that colour should really be upon the surface of a body, in order to make me see that colour, any more than it is necessary for pain to be in a needle, in order to make me feel it when I am pricked. It is sufficient that as the needle causes a certain disposition in the fibres of my body, by the means of which I feel the pain, so that particular rotation, which is in globules repelled from the surface of a body, should cause another motion upon the nerves of the retina, which carried from these to the brain excites in me the idea, or, as they call it, the sensation of colour. Thus, if in any body there be a certain motion by which it pressed the globules of the second element, and these globules be carried to our eye, they will raise in us the idea of light. A certain configuration of particles, or perhaps certain little animals which are in bodies, by playing upon the nerves of the tongue in such a particular manner, raise in us the sensation of some taste. These sensations are generally raised in us by means of certain bodies, and because we see neither their particles nor the little animals which are in them, the globules of the second element, nor the impression which is made upon our nerves, we ascribe to

those bodies both light, colours and taste, which in reality are only in ourselves. Reason at length convinces us of the illusion that our imagination continually puts upon us, and assures us, that the delightful and hitherto undefined taste of the pine-apple, the pleasing verdure of a meadow, and even the light of the sun which animates and revives the whole universe, are all our own.

I understand you, said the Marchioness; we are enriched at another's expence, and are like antient Rome, which founded its grandeur upon the spoils of the whole universe. Philosophy would be in a bad state, answered I, if its rights had no better foundation, than those of policy and ambition. I see you have not yet a right notion of it. In order to convince yourself that philosophy is no usurper, but only takes its due, press one corner of your eye with your finger, and you will see on the opposite part a round flame of a reddish colour. In this case there is certainly neither light nor colour without your eye. The only reason of your seeing them is the pressure which your finger makes upon the nerves of your eye. The globules of light, which flow from the surfaces of bodies, occasion the same effect upon the eye as your finger, only their operation is more imperceptible. The different disposition and configuration of the parts of a body, are the reason why the globules make different impressions upon us. The power of a body's exciting in us the idea of any particular colour, consists alone in this disposition, and the configuration of its parts. Is it not evident from hence, that if this disposition be changed, the colour is changed also? which could not happen if the colour was really in the parts of the body itself. Coral, which is of a fine red, if it be ground to powder turns pale. One liquid mixed with another changes its colour. The reason of all this

is, that the disposition and configuration of the parts of these bodies are changed by being ground or mixt, and from hence they transmit the light to us in a different manner, and consequently our idea of the colour is changed; from no other reason proceed the venerable white locks of old age; the transient whiteness of many animals of the north in winter. From hence too it is, that certain roses in China are in the same day both white and purple. From this cause arises that surprising variation of colour which generally follows the change of passions in the camellion, which has furnished the moralists and poets with so many allusions, the antients with so many fables, and the moderns with so many observations. And what is it else but one disposition which hinders us from seeing you goddesses when you first rise, and another which gives you to our sight and adorations after you have spent two or three hours in the sacred rites of the toilet?

I perceive, replied the Marchioness, that there is nothing secret to philosophy; we may hide ourselves from men, but not from philosophers. And indeed to what purpose would it be for us to endeavour to conceal ourselves from a set of people who are quick sighted enough to discover the globules of light endowed with a certain motion, and those nerves and fibres to which this motion is communicated and thence conveyed to the brain? A sight which mortal eyes have never yet penetrated into. But I must confess, I stand in need of your assistance to guide me through this obscure labyrinth. I do not see what relation all these motions have to any colour that I have a conception of. This is a thing which seems to me quite different from these motions. Have you any better conception, answered I, of the relation between the idea of pain, and a separa-

tion of the fibres of your hand? Or between the idea of hope and a certain motion in the muscles of an eye? And yet you see that these things are in fact connected, and that the one is the cause, or at least the occasion, of the other. You seek for more than it is possible to give you. Unhappily for us, those things which are of the greatest importance to human knowledge are the most doubtful. Who can tell you in what manner objects occasion certain ideas in the soul, and how the soul on the other hand gives certain motions to the body? how the soul which is unextended, yet is present in every part of our whole machine, and though incapable of being seen or felt, yet sees and feels every thing? Philosophers can with a great deal of ease transmit the motion of the globules of light, or any other motion, to the nerves, and from these to the brain, where they all terminate, either by means of a fluid that runs through them, or a certain tremor raised in them. Nay, philosophers will go yet farther, and transmit this motion to certain parts of the brain which are imagined to be the seat of the soul. But how these motions, when they are arrived to the brain or seat of the soul, should produce in it different ideas, is an absolute mystery. This passage, which in appearance is so short, is to philosophers what the innavigable ocean was to the antients. What communication, what connexion can there be between body and soul, between extension and thought, motion and idea, matter and spirit? What sort of communication these can have with one another, is beyond the reach of our imagination. The same, answered she smiling, that Æneas had with the shade of his father Anchises in the Elysian fields. They mutually communicate the most agreeable things in the world to one another.

But when *Aeneas* attempts to embrace the old man, he vanishes away and is dissipated into air.

you ~~We may~~ draw a fine allegory from this passage, answered I, which would have done great honour to a learned and musty commentator of the last age. Now in order to put your allegory in a clear light, and to let you see on the other hand that nothing is able to discourage a set of people brought up and educated in the midst of difficulties, some of them will tell you, that there is a certain correspondence or pre-established harmony betwixt soul and body, so that though they have no more connexion with each other, than a harlequin dance in our operas has with the death of Dido, or the fate of Rome; yet by virtue of this pre-established harmony, at the same time that certain motions happen in the one, certain ideas and desires arise in the other. In short, that they are like two clocks independent of each other, whose weights are adjusted in such a manner, that when this strikes one, that shall always strike two, and so on. Your *Des Cartes* will tell you that upon occasion, when bodies without us in the material world excite certain motions in our body, the soul sees certain ideas in the intellectual world. So that in the material world, you have nothing but extension, and certain motions, and configurations, and whatever other qualities you possess, and which render you so agreeable and charming, exist only in the intellectual world. Others will tell you, that by means of certain motions in the body, God reveals and displays certain ideas to the soul. But they have so little regard for any connexion between these motions and our ideas, that they affirm, we might as well hear with our eyes, or see with our ears, provided the laws of the union of the soul and body were different from what they now

are, which is not impossible, since these laws are merely arbitrary. One of the laws of this union is, that when there are certain motions impressed on one of the membranes of the eye, the idea of light should be raised in us, and in the same manner, when certain motions are made upon a membrane of the ear, we should perceive the idea of sound. And as these things are independent of one another, why might not the idea of light arise from certain motions upon the ear, and that of sound from certain motions impressed on the eye?

And why, said the marchioness, may we not rather suppose that there are some secret dependencies between these things, which your philosophers may not have been acquainted with? The vulgar hide their ignorance under the vail of obstinacy, and do not the learned endeavour to conceal theirs in doubts and questions? Your suspicion at least is reasonable, answered I. Our horizon is but faintly illuminated with the beams of a glimmering twilight, and we pretend to see as clearly as if it was full day. We continually act, especially with regard to metaphysics, as Columbus would have done, if he had pretended to write us a complete description of America, and given an account of its inhabitants, rivers and mountains, when he had only seen a little tract of this country, and did not know whether it was an island or a continent. We reason upon the chimeras of our own fancy, we destroy and build systems, we raise doubts, and think to resolve them without agreeing upon so much as their first ideas. One of the most elegant geniuses of England, who in our days has revived the polite court of Charles II. in that happy country, in a little, but very valuable piece, which he wrote against one of the most celebrated metaphysicians of

our time, compares those gentlemen to fine riders in a "manage, who show their address and dexterity by making their horse go backwards or sideways, and all ways, and at length after having laboured round and round for two or three hours, get down just where they got up." However it be with these metaphysical jockies, it is certain, that some things produce others very different from them. The Americans without doubt, would be extremely surprized to hear that certain cyphers, as the letters of the alphabet, could transmit the history of a nation to posterity, and furnish two people with means of communicating their thoughts, quarrelling or making love at the distance of four thousand miles, just as well as if they were present with each other. And would not the Chinese be greatly astonished to see that certain marks drawn upon lines should produce sounds, concords, and in short, a concert of music?

As I imitate these in their surprize, replied the Marchioness, I will imitate them too in their docility, which they discover in embracing whatever we teach them as reasonable even at the expence of their self-love. We must then solemnly abjure all those charms which you call roses and lilies, and submit to that philosophy which deprives us of them, perhaps to give us in exchange some greater good. I admire your moderation, answered I, in agreeing to this Cartesian philosophy, which, to say truth, is somewhat injurious to fine ladies. When the philosophy of Aristotle was in vogue, who asserted that qualities were really in bodies, the ladies might be something vainer of their beauty. But now they must renounce the very things upon which that vanity was principally founded. It is true, that with globules alone, a bare disposition of parts,

you will still continue to make the same conquests as you did before with the help of colour itself. But it is true on the other hand, that it is for ever gone without any hopes of being recovered again. However, if you are afraid that this system may do you any sort of injury, you need only name the person whom you have a desire to please, and I will promise you never to let him into the secrets of philosophy.

Till there appears another system to deprive us of that disposition of parts which this leaves us, replied she, I do not see, that we have any thing to fear, since after all, one certain disposition has only one certain idea affixed to it. So that the disposition, which excites the idea of a fine red in you, cannot produce that of a yellow or brown in another person. And thus I think we are secure. Seriously, answered I, I do not at all doubt that beauties are secure in any system of philosophy whatever. But that a certain disposition of the parts of a body should excite the same idea in all men, is what I cannot assure you of. Who can tell whether the leaves of these trees that I see of one colour which I call green, may not appear to your sight of another colour which I should call red or yellow, or perhaps of some other colour, of which I have no idea? You would render me too philosophical, said the Marchioness, and after this I shall be utterly at a loss how to converse with mankind. You have made me already rob bodies of light, colours, taste, smell, and every other quality which these have never made any scruple to grant them, and would be greatly offended at any attempt to take them away. But not content with all this, you would have me confess that a colour which appears green to some, should seem to others red, yellow, or some other colour,

perhaps, of which I have no idea. Is it possible to offer a greater affront to mankind, than to contradict a thing they are so sensibly persuaded of, and assert that they do not all see colours in the same manner? I will venture to tell you still more, answered I, for to shew a regard to mankind, whom you seem so fearful of offending, in this point, is not possible for any one who has ever conversed with them. Who can tell whether these very trees, which I see of one certain height, may not appear to you of another? So that what I, for instance, call ten foot high, may appear to your eyes of a height which I should call eight, or twenty feet. You have a mind to divert yourself at my expence, said the Marchioness, interrupting me. We both agree in calling this tree so many foot high, as well as in calling the leaves green. How then can what you say be true? We agree, answered I, in words, but perhaps not in things. Two people, one of which should give a chief magistrate the name of king, from whose good or ill administration depend the life and properties of his subjects; and the other should give the name of king to a chief magistrate, who is only the ratifier and guardian of the laws of nature, to which he, as well as the rest, is subjected: these two people would both agree in the sound, by which they denote their chief magistrate, but not in the idea which they annex to this sound. Both you and I had a certain measure at first shewn us, which though it appears to you of a different size from what it does to me, yet both of us agree in calling it a foot, because we are told that mankind distinguished such a measure by that name. According to this, which is the rule of our mensurations, we both say that this tree is so many foot high, though it may appear to me of a greater or less height than it does to

you, and so every other thing in proportion to the different idea we may possibly have of a foot. Who can tell then, but you may appear to yourself, and I to you, like one of Gulliver's Brobdingnagians; on the contrary each of us may appear to my sight as small as a Lilliputian does to yours, and who knows too but you may see the whole world after the proportion of my Brobdingnagian, and I of the same size as your Lilliputian; so that if it were possible for us to see with each other's eyes, which would be a good exchange for me, you would despise the diminutive size of my Colossuses, and I should tremble at the gigantic stature of your pigmies. We may easily transfer the same way of reasoning to colours. We here too agree upon names, but may very probably differ in things. Each of us, for instance, calls the leaves of this tree green, because we were at first told that the colour of leaves was green; but it is possible, that if things could appear to your eyes as they do to mine, you would be surprized to see these trees and the whole country clothed in a colour which you perhaps might call purple or some other. Because we see that all men resemble one another in the make of their body, when they have all two eyes, one mouth, two legs, and two hands, we are led to imagine from thence that they must all resemble each other in their ideas, and from hence arise many inconveniences in society which would not have happened, had men been a little more philosophical than they are. From hence it is, that a politician, when you are thinking on something quite different from his projects, will plague you with a long account of the end and intentions of all the privy councils in Europe, and the division which he has already made in Italy; for he thinks it impossible that a man, who resem-

bles him in his outward appearance, should not equally interest himself in his visionary schemes. From the same cause a lover will talk you dead with the history of his continual sighs and hopeless passion. In short, this mistaken notion gives birth to numberless other inconveniences in society. None greater, said the Marchioness, than the philosophers who endeavour to reverse the ideas that mankind have formed to themselves, and make us believe that we do not all see the same thing of the same size and colour. Cannot you find some method to explain to me whether the world really appears so different to different persons, as you say it does?

It is not possible, answered I, to find such a method as you require, unless there could be any one measure which all men were certain of seeing absolutely of the same size, and certain colours which, in the same manner, they could be assured, appear the same to all eyes, and to these they might refer all other colours, as well as all other sizes to the measure. As those two people who make use of the same word *king* to signify their chief magistrate, though the one be in effect very different from the other, can never come to a clear explanation of the different ideas they would annex to the same word, unless they define and compare it with other words; and more simple ideas, such as both parties are agreed upon. Now red, yellow, and the smallest imaginable measure, are in themselves such simple ideas, that they can neither be defined nor compared with other ideas more simple. Therefor we have no way of knowing whether all men have the same conceptions of them, or not, so that mankind are much to blame in being so confident that the world appears in the

same manner to all, for it is a great chance but they are mistaken in this affair.

But what ill consequences can there possibly follow from our saying that the world appears to every single man different from what it does to all the rest? Nay, if we should go farther, and say that even the world itself does not exist, and that all these bodies, this sun, these stars, and these fine ladies, are nothing else but dreams and appearances. There is one philosopher who affirmed, that a person need only to have slept once in his life-time, to be convinced of this. So that while some are disputing about the manner in which the world exists, others absolutely deny that it exists at all. But though I have slept more than once in my life, I will not preach up a system to you which would mutually destroy us both. I will rather assure you, that though we really should see the world in different manners, yet I am willing for my own interest to consult your preservation. They will all agree in saying, that this tree is so many feet high, and the leaves green, and that you are of a just height and a fine complexion; and does not this difference of ideas diffuse an infinite variety over the whole system of nature, which seems even in the minutest things to take a pleasure in diversifying herself a thousand ways? but what a pleasure must you find in imagining yourself to appear to some under the height of a wax baby, and to others as tall as the image of Flora at Farnese! to some of an azure complexion, with the green locks of a Nereid, and to others of a vermilion dye, and adorned with the rosy tresses of Aurora, and under these different aspects, to be agreeable to all, and adored under various forms, as the goddesses formerly were among the antients. I must confess this imagination, that every sin-

gle man sees the face of the world in a manner different from all the rest, though, if you will have it so, it be a doubtful point, gives me so much pleasure, that I make no scruple of carrying it beyond size and colours, to taste, smell, and all other qualities. I said, *if you will have it so*, only out of complaisance to you; for if it be considered how very different the nature of things is from what it appears to our sight, since we reckon, for instance, those bodies to be smooth and solid, which are in reality full of pores, cavities, and risings, and imagine them to be endued with colour, taste, and other qualities which exist only in ourselves: when we consider too that the same bodies have a different appearance according to their distance and the other circumstances in which they are seen; when all this, I say, is well considered, I do not know whether we may not affirm that every single man sees them in a different manner from all the rest, and that our judgment is as much deceived in supposing that the same things raise the same ideas in different persons, as it evidently is in the other respect; at least we may reasonably doubt whether it be not so. You will say perhaps, that this is raising doubts and questions to hide our ignorance. But it is however one of the parts of a philosopher to search for motives upon which he may form rational doubts upon things, or rather, such is our misfortune, this is the best part of philosophy. However, we every day clearly see that the same objects do in effect appear differently to different persons: not to say any thing of the more important affairs of morality, law, and politics, where what is esteemed in one nation an object of veneration and respect, is reckoned scandalous and detestable in another. Did not the ladies in one age drive all the colour out of their cheeks, and

affect a pale languid look, which were capable of inspiring the most lively sentiments, at a time when a painted face would have been as shocking as a fury. But in the next age, this very fury becomes a Venus, and instead of sighs and fine speeches, the pale beauties are recommended to the care of a physician, or the use of Spanish wool. Were not the very same grasshoppers, that weary us with their troublesome chirping, called by an ancient poet the sweet harbingers of the summer? There are whole nations who esteem black teeth a singular beauty, and others who paint one eye white, and the other red or yellow. In some other countries, a beau sacrifices and gashes his face to appear more agreeable to the eyes of a brutish creature, who is alone the mistress of his heart. An olive complexion joined to a long head, a pair of deep sunk black eyes, a flat nose, and the feet of a baby, are charms that make great havock in the hearts of the Chinese, and occasion whole volumes of gallant verses and love epistles. Our Galatea's and Venus's would not get so much as one *billet doux*, or a single ode there, but would be looked upon as mere caricatures. In the same country, learning is a step to the highest honours of state, and there is more ceremony in making a doctor there, than the Polanders use in electing a king. Are not music and dancing, which are with us, as antiently among the Greeks, an exercise for persons of the first rank, looked upon in Persia, as they formerly were at Rome, as scandalous employments? And would not the same ladies, who cause so many commotions and disturbances in Europe, be close confined in a seraglio and guarded by eunuchs in the eastern countries? If you will not consent to admit a different appearance of things between men, yet you must allow it to be so with regard to

nations, as for instance, between us and the orientals, unless you will except some particular follies which seem to have usurped a more extensive and universal right over mankind. The antients Greeks, the Romans, Orientals and Americans, though separated from each other by such vast tracts of land and so many seas, yet all agreed in the ridiculous notion, that when the moon was in an eclipse, which is occasioned by the shadow of the earth, that deprives it of the sun's light, she was in great danger, and laboured extremely hard, and imagined they could be of service to her by howling, rattling with their timbrels, and making the most horrible outcries and noises they could possibly invent.

I find, said the Marchioness, you begin to grow a little more moderate after this philosophical enthusiasm which had carried you so far, that you endeavoured to reverse the whole order of things. But you have now consented to grant, that we think alike in these opinions which you call ridiculous. As to all the rest, I am very well satisfied, if you place this difference of ideas at so great a distance as is between us and the Oriental countries.

In order to make you still easier, answered I, we will at present place these different ways of conception at a distance still greater, and in proportion as you grow a greater proficient in philosophy, we will bring them gradually nearer to us, till at last we will agree to put some difference between your ideas and mine, and from thence between the two eyes of some persons to whom the same object appears bigger when seen through one eye, than it does when looked upon by the other.

How is this possible, said the Marchioness? There is no end to your visionary fancies, and you seem resolved to

put me to the utmost proof of my credulity. Not contented to make a difference of ideas between different persons, you carry your notions so far as to make this difference between the two eyes of the same person. I must confess, I think this a very daring way of proceeding. Did not Gassendus, answered I, one of the celebrated philosophers of the last age, affirm that he saw the characters of a book larger through one of his eyes, than the other? You see the fault is not to be thrown upon me, but upon the eyes of Gassendus. You would find many other persons with these sort of eyes, if they were but as curious in examining their senses as they are diligent in making use of them. To some persons an object is said to appear green, when looked at through one eye, and yellow or blue, when seen by the other. But do not we see every day, that what one person esteemeth cold, another calls hot? Or rather do not we ourselves think the same thing to be cold or hot, according to our different dispositions? Would not the very same thing that Milo might have thought smooth as a mirror, appear rough as a nettle to that luxurious youth whose bed was strowed with roses, and who could not sleep for a whole night, because a single leaf happened to be doubled? And do not these different sensations which are so extremely opposite, as hot and cold, smooth and rough, proceed from a different disposition of the sensitive organs; from a different affection of the nerves, or the more or less delicate texture of the parts appointed to carry these sensations to the brain? and is it not very probable too, that these differences may be in that membrane of the eye, upon which the images of objects are depicted, and in the filaments of the optic nerve which transmit these images to the brain? Hence it would

follow, that as we receive different sensations of hot, cold, smooth, and rough, we should find the same difference in our sensations of colours, and the like.

In order for me to enter into your sentiments, said the Marchioness, you must explain what you mean by saying that the images of objects are depicted upon the membrane of the eye; and that the optic nerve transmits those images to the brain? Do you know, answered I, that an explication of this will be no less than an explication of a vision it self? So much the better, said she: indeed it seemed pretty strange to me, that after you had spoke so much upon the different ways in which it is possible for us to see, you should be silent upon the manner in which we really see. I will not defer this explication any longer, answered I, and I shall be extremely happy if my shewing you in what manner you see me, may induce you to look upon me in a different way from what you have hitherto done.

Light is principally subjected to the two accidents of *reflexion* and *refraction*. *Reflexion*, according to the Cartesians, happens when by collision of the globules of light with the solid parts of bodies, these globules are repelled back again, just as a ball rebounds when it is struck against the earth. And it is by this reflected light, that we see all bodies, the moon, the planets, heavens, and every thing else, except the sun, stars, fire, and all those other bodies here below, which shine by their own light. *Refraction* is caused when the globules of light in passing through air, water, glass, *etc.* meet with the pores and cavities of those bodies, so that the ray, which is only a chain or series of globules, breaks and is turned out of its proper path, and takes a different direction in its passage from what it had before. Pellucid or transparent

bodies which suffer the light to pass through them, such as water, air, diamond, and glass, are called *mediums*. Hence *refraction* is said to happen when light passes from one *medium* to another. And this *refraction* is greater or less, that is, the rays are more or less broken and turned aside from their path, in proportion to the different densities of the *mediums* through which the light successively passes. Thus for example, the rays are more broken in passing from air into glass, than in passing from air to water, because glass is much more dense than water; and for the same reason they will be more broken in passing from air to diamond.

If this was a proper time, said the Marchioness, to make criticisms upon poets, it might be said, that Tasso has not expressed himself very accurately, when speaking of Armida, he says,

As limpid streams transmit the unbroken ray, etc.

Poetry, in these verses, does not seem to agree with optics, which will not allow that a ray can be transmitted unbroken. Tasso perhaps, answered I smiling, would be understood to speak of those rays which fall perpendicularly upon water or crystal, that is, without being inclined, with regard to the surfaces of those *mediums*, either to one side or the other; as a thread would fall upon the ground if it had a weight fastened to it: for in this case the rays pass on without being broken, and continue to proceed in the same path as they first set out in: but the truth is, that poets do not address themselves to philosophers nor to you, who have nothing but *refractions* in your mind: but they write for the people, and consequently must often make use of vulgar prejudices and opinions. And provided the images be lively, the passions strong, and the num-

bers harmonious, we may pardon them a mistake in optics. What do you think of Ovid, who has perhaps stretched the poetic licence too far, and made the sun in a day run through all the signs of the Zodiac; whereas according to the exact rules of astronomy, his diurnal course is confined to about the thirtieth part of only one sign? In the second book of the *Æneis*, that master-piece of sublime poetry, there is a very fine image, which, if examined by the laws of optics, would lose all its justness. *Æneas*, after he had been assured by *Hector* in a dream of the irreparable ruin of his country, ascends a turret, and there discovers the treachery of the Greeks, whose dreadful effects appeared from every quarter. The palace of *Deiphobus* already levelled to the ground, his next neighbour *Ucalegon* on fire, and the flames of that city, which a ten years siege had attacked in vain, dreadfully reflected by the waves of the sea. Now in the situation in which *Æneas* stood this could not possibly be; for the opticians will tell you, that in order for him to see the flames of the city shine upon the sea, the sea must have been placed between him and those flames, which it was not. But who would not excuse this error, which can be seen only by a very few, for the sake of those fine verses which all the world admires?

But to return from poetry to physics, a transition which you have rendered very familiar to me, the manner in which the rays of light are broken in passing from a rare to a dense *medium*, as from air to glass, is different from what it is when they are transmitted from a dense to a rare *medium*, as from glass to air. I would be understood, always to speak of the rays which fall upon these *mediums* obliquely, and with some inclination; for as I mentioned to you before, those rays which fall perpendicularly do

not suffer any deviation. If you suppose then, that a ray of light coming from the air should fall upon the surface of a glass, it will be broken in such a manner, that after its trajection, it will be less inclined to the surface of the glass, and immersing will approach nearer a perpendicular. After the same manner, a ray of light proceeding from your eye would strike the middle of this basin, provided it were dry. But supposing it filled with water, as it now is, the ray could not continue its course directly to that point as at first, but in its transmission through the water would be bent in such a manner that it would fall on one side, and strike the basin in a point nearer to us. These are all the lines and figures that I will draw you, to explain the present subject.

What need is there of lines and figures, replied the Marchioness, to understand that a ray of light passing from air into water or glass, will be bent in going towards it, and approach nearer to a perpendicular? And does not the contrary happen, when the ray passes from glass into air? Yes certainly, answered I; the ray in this case is more inclined after its trajection to the surface of the air, which immediately touches the glass, it becomes more unlike a perpendicular, and places itself as it were behind, the surface of the earth.

These *refractions* of the rays of light which were known, though very imperfectly, to the ancients, and to the consideration of which we in great measure owe the perfection of astronomy, are the cause of an infinite number of strange and amusing phenomena, which we every day observe; such as objects appearing out of their place when viewed through a *prism*: an oar broken in the water, and the surprize of seeing ourselves deformed and crooked when in a bath.—This is the very thing, said she, interrupting

me, that I lately observed when I was in the bath, and I was extremely surprized and puzzled to find out the reason of it. It is nothing else, answered I, but the *refraction* which the rays suffer in passing from air into water. These *refractions*, besides what we have already mentioned, are the cause too why we see the bottom of vessels and rivers much deeper than they really are, and that sailors after a long and tedious voyage, have the pleasure of seeing and saluting the land, much sooner than they would otherwise do. This too is the reason that the sun and full moon appear to our sight of an oval figure when near the horizon, and many other things of the like nature, which proceed from hence, that the rays in their passage from these objects to our eyes are refracted, and come from places different from those where the objects themselves are. The eye, which is not sensible of these *refractions*, always refers and transports the objects to those places from whence the rays appear to proceed, or in other words, it sees them in the direction of the rays which penetrate and strike it. Hence it is, that the figure and situation of things which are seen by refracted rays, come to be changed. If, without knowing any thing of the science of optics, the first time I had the honour of seeing you, a *prism* had been placed before my eyes, which by *refracting* the rays which proceed from you to me, had given them the same direction which they would have had if they had come from the sky, you would certainly have appeared to me to have been transported into the world of chimeras, and incompassed with an infinite variety of colours, and I should have intreated you to descend, as Endymion did the moon, and addressed myself to you in some florid description of a shady grove or lonely vale, in order to tempt you from the stars. And all this fine delusion would have been occasi-

oned by that direction which the *prism* had given to the rays, which would have flowed from you to my eyes.

I fancy, said the Marchioness, that mankind always look upon those, who are in a condition much superior to their own, through certain *prisms*, which make them appear as if they were transported to heaven, to revel upon ambrosia, enjoy the conversation of the gods, and be surrounded with glory and happiness; whereas the more they are elevated above others upon earth, the more subject are they to the sport and caprice of fortune. This comparison will appear still juster, answered I, upon this account, that as when we quit the *prism*, we see the objects again return to their proper place: so when we forsake the opinions of the vulgar, and substitute those of good sense in their room, these demigods appear nothing more than other men, and in a condition not greatly to be envied. But to return to our subject: A philosophical eye every day discovers an infinite number of strange and diverting phenomena arising from the change of direction produced in the rays of light, not only by *refractions* but by *reflection* too. From hence proceed all the wonders of concave glasses, by the help of which, that poet, who wrote a dissertation on the nature of bees, could discern the small members and diminutive parts of that noble and industrious insect, and magnified them to that degree that each of them seemed as big as a dragon. With these glasses too the vestals rekindled their sacred fire, whenever it happened to be extinguished. From hence arose the fables of Archimedes and Proclus; and ignorance and imposture have rendered these glasses one of the favourite instruments of magic. But among the phenomena which arise from a change made by reflection in the rays of light, you will

perhaps be surprized to find one which is every day present with you, and which perhaps you have never yet considered as a phænomenon, much less a matter of wonder. What phænomenon can this be, said the Marchioness, to which I have paid so little regard? It is, answered I, the image of your self, which appears beyond the looking-glass every morning, when you hold a consultation with the Graces in what manner it will be best to give an artificial negligence to your hair. This representation of your self proceeds from hence, that all the rays, which flow from all the points of your face to the looking-glass, are reflected in such a manner to your eye, as if they proceeded from as many other points as there are in your face, equidistant from each other, and as far beyond the glass, as you are of this side of it; and consequently you see your image at as great a distance from the glass, as you your self are, and exactly like you; and from the pleasure this beauteous representation affords you, you easily conceive what pleasure the original must give to others. The celebrated Milton has in his sublime poem finely described the delight and surprize of Eve the first time she surveyed herself in a fountain,

—— *That stood unmov'd*

Pure as the expanse of heav'n—.

And this image of herself appeared so charming, that, like another Narcissus, she afterwards ingenuously confessed to Adam, that though she thought him fair, yet he seemed,

—— — *less fair*

Less winning soft, less amiable mild,

Than that smooth wat'ry image——

Does not this passage of Milton convey some malicious in-

finuation, said the Marchionefs? And is not his real meaning that the sight of a husband gives a woman less pleasure than even an image or a shadow? However, I agree that our first parent was in the right to admire this fine phenomenon, and I have been greatly to blame in my neglect of it; but we are too early accustomed to the sight of these things, for them to make a strong impression upon us. If any one had told me a few days ago, that certain rays, flowing from my face, would have been reflected from the looking-glass, I should have believed it to be one of those usual enigma's which gallantry borrows from tradition, or founded upon the authority of some old romance. But I confess that from this time, I shall survey myself in the glass with a sort of philosophical pleasure.

There is no greater pleasure, continued I, to philosophers, than that of observing the various sportings of the rays of light, in passing through a *gibbous* glass, or one that is convex on both sides, and from which its resemblance to a grain of *lentille*, is termed a *lens*. And upon this depends the explanation of vision. If two rays of light mutually *parallel*, that is to say, which always keep the same distance from each other without approaching nearer or removing farther off, like the espaliers of these walks, fall upon a *lens*, by means of that *refraction* which they suffer, they are united beyond it, into one point that is called the *focus of the lens*, which is more or less distant in proportion as the *lens* is more or less convex. So that the greater the convexity, the less will be the distance of the *focus*; and the less the convexity is, the distance of the *focus* will be the greater. And this distance of the *focus* is what distinguishes the *lens*: as for instance, we say this *lens* has so many feet of *focus*, and another so many, just

as we say such a machine can raise the water to such a height, by which we would signify the force and activity of it. I fancy, said the Marchioness, that the reason why this point is called a *focus*, is because a candle may be set on fire when placed there, as I once saw done by a person who undertook to light a candle without the help of fire by the sun. He might safely have engaged, answered I, to light the candle not only without fire, but even with ice. For a *lens* made of ice in a little space of time produces the same effect as one that is formed of glass. How many impertinences might this have furnished the poets with in that time when their language was,

*See guarded by the watchful powers of love,
Fair Delia slumbers in the peaceful grove;
Struck with the sight, let wond'ring mortals own,
Amidst the gloomy shades, a radiant sun!*

But the reason that you give is a very good one: the burning which follows in that point where the *lens* unites the rays which were at first parallel, and forms them into a flame, is the very reason why it is called the *focus*. All the rays, which are not mutually parallel, but in going from a point keep continually removing from each other, and which are called *diverging* rays, unite beyond the *lens* in another point, which is always more distant than the *focus* of the *lens* itself. Hence we say, that a convex *lens* renders the parallel and diverging rays converging. For those rays are called *converging*, which proceeding from various parts, have a tendency to unite themselves in one point. Just as the alleys of those woods which are formed in the shape of stars, continually approach to one another till they all meet in the centre. These walks, said the Marchioness, interrupting me, might be called diverging, with

regard to one in the centre of the wood, from whence they proceed, always removing still farther from one another. You only want, Madam, answered I, to turn over Euclid and Apollonius a little, and sometime put on an abstracted look, and you will be a complete geometri-
cian.

But to follow the tract of these rays as we have begun — the more that point, from which the diverging rays set out, is distant from the *lens*, the nearer the *lens* and its *focus* is that point where the rays unite; and so on the contrary, the nearer that point from whence the diverging rays proceed is to the *lens*, the farther off from it and its *focus* is that point where they unite; provided however, that the point from whence these rays proceed be not at such a distance, that instead of uniting they are thrown out of the glass either diverging or parallel. Opticians, in order to find out the innumerable variations which these rays may form, make use of a certain science called *Algebra*, which after having extended its empire over all the regions of natural philosophy, has since by the ingenious contrivance of interest been appropriated to civil uses, to determine the chances of those games which are the most subject to the caprices of fortune, and has even insinuated itself into the litigious provinces of law and morality. By the help of this science, they have always certain letters at hand, called symbols, connected with each other by certain signs: with these, provided they know the quality of the *lens*, that is, the distance of its *focus* and of the point from whence the rays proceed which fall upon the *lens*, or the distance of the point to which the rays tend if they should fall converging upon the *lens*, Opticians can tell you in a moment, whether the rays will unite or not, whe-

ther they will go out of the *lens* diverging or parallel, and in what point they will unite. This looks like a species of magic, which perhaps would not have escaped unpunished in that age, when it was a crime to assert the motion of the earth, and the existence of the Antipodes.

The uniting of the rays diverging from several points, into the like number of points beyond the *lens*, which seems in itself a very indifferent thing, supplies us with one of the finest sights you can possibly imagine. If to a hole made in the window-shut of a darkened room, you apply a *lens*, and over-against this at a proper distance there be placed a sheet of white paper, you will see all the objects which are without the window, especially those which are directly opposite to the *lens*, inverted and painted upon the paper with a beauty, vivacity and softness of colours that would make a landkip drawn by Claude Lorrain, or a *visito* by Canaletto, appear faint and languid. You will perceive the distance of the objects exactly the same as you would do in a picture, that is, the smallness of those objects which are far off, from a little confusion and obscurity, from a certain faintness of the colours, and in short, from a most exact perspective the grand secret of that happy art of delusion, painting, which accompanies and assists all I have been describing. It is impossible to express to you the pleasure that results from the motion and life which animates this fine piece: the trees are really agitated by the wind, and their shadow follows the motion. The flocks bound upon the lawns, the shepherd really walks, and the sun-beams play upon the waters. Nature draws her own picture inverted and in miniature.

It is pity, said the Marchioness, that so fine a picture drawn by the hand of so excellent a master, should be turn-

ed upside down, which I am as much at a loss to find the reason of, as I am of the manner in which it is formed. Let us suppose, answered I, without side of the window over-against the *lens* an arrow to be placed horizontally, that is, even with the bottom of the window: let the point of this arrow be on the right-hand, and the feathers on the left. Suppose too that the extremity of the point emits rays upon the *lens* which entirely cover it. These rays unite beyond the *lens* itself in another point, but in passing through the *lens*, instead of being on the right hand as they were at first, as proceeding from the point of the arrow which we supposed to be on the right-hand, they change their situation, and are placed on the left. In the same manner the extreme point of the feathers throws rays upon the *lens* which unite in another point, and after their passage through the *lens* are turned from the left to the right-hand. Just in the same manner as if a person held two sticks, one in each hand, and should cross them together; that which before the crossing was on the right will afterwards be on the left-hand, and on the contrary, that which was on the left will be on the right. Now the rays, that fall upon the *lens*, cross each other, just as these two sticks do in the point where they touch. The same may be said, if the arrow should be set upright. Those rays which proceed from the top of it, after being crossed and passing through the *lens*, remain at bottom, and those which came from the bottom at top. Thus you see the whole situation of the rays is changed. That which was at top is placed at bottom, and what was at bottom appears at top. That on the right-hand is turned to the left, and that on the left to the right. If a sheet of paper be then placed behind the *lens* in the place where

these rays unite, they will draw you an image of the arrow in which the point shall be on the left hand, and the feathers on the right, or in other words, the image will be the reverse of the object. You may easily transfer what I have said of the arrow, to a landskip, a piazza, or any other object, with this difference however, that all the parts of a landskip or piazza cannot be equally distinct in the picture as those of the arrow are, because the rays unite at different distances from the *lens*, in proportion to the different distance of the points from whence they flow. If, for instance, an object in the middle of this walk is seen distinctly upon the picture, as it will be if the paper be set in a place where the rays which come from it unite, those objects which are nearer cannot be distinct, because the point where the rays unite is at a greater distance; neither will those objects which are farther off be distinct, because the point where their rays unite is nearer the *lens*, and consequently the rays, as well of the one as the other, fall upon the paper disjointed, and only form an image there which will be very dim and languid, or in other words, confused; so that for those objects which are far off, we must place the paper nearer the *lens*, and set it at a greater distance when we should see those which are near.

It will now be necessary, said the Marchioness, that you should provide your self with a *lens*, and give me a sight of these fine landskips all round us upon a sheet of paper. For I must confess, I have a great curiosity for this, both as a woman, and as a woman whom you have rendered half a philosopher. I wish, answered I, that I had one with me to satisfy your curiosity this moment, which by what you say must be extremely strong. But I will satisfy you as soon as I am able with a view of this *camera obscura*.

But what will you imagine if I say to you when we are in it, suppose yourself to be placed in one of your eyes, and to see every thing that passes there?

The *camera obscura* represents the inside of our eye, which is nearly of the shape of a ball: the hole in the window is the pupil which is in the fore-part of the eye, and appears in all as a dark hole, sometimes greater, sometimes less. The *lens* is the chrystalline humour which is exactly of that figure, and is placed over-against the pupil, and suspended by certain little fibres called the ciliar processes, which proceeding from a coat or very thin skin which incompasses the inside of the eye, are fixed in the edge of it: the paper on which the image of objects is depicted, is the *retina*, composed of the filaments and medullary substance of the optic nerve, which is fastened to the eye behind, and is the great channel of communication between that and the brain. The spaces which are between the fore-part of the eye and the chrystalline humour, and between this and the *retina*, are filled with two humours less dense than the chrystalline, but denser than the air. By the help of all this *apparatus*, external objects are pictured upon the *retina* in miniature just as in the *camera obscura*, and thus we see.

Really I did not think, said the Marchioness, that I should be transported thus in an instant from the *camera obscura*, to the inside of my eye, nor that the fine picture, you before described, had so much relation to vision. Many must have observed this, answered I, before you, without suspecting any such relation. If there be a hole made in any room which is otherwise dark, and this hole does not exceed a certain bigness, this will be sufficient to shew you those objects which are over-against the hole,

painted upon the opposite wall or the floor of the chamber. Is there no need of the *lens* then, saith the Marchioness, in order to the production of this picture? It is necessary, answered I, to give it in some measure the finishing stroke. But even without the *lens* if the hole be small enough, and the opposite wall or the floor not very distant, the rays which pass through the hole are near enough not to appear confused, and may draw a tolerable picture of the external objects upon the wall or the floor.

If the chrystalline humour becomes opaque, which is what forms a cataract, there is no other remedy in this case to recover the sight, than by depressing the chrystalline humour, and cutting away the fibres which hold it suspended, and then some faint representation of the objects may be drawn on the *retina* of those unhappy persons. But as the picture in the dark room is much weaker and more confused if there be not a *lens* applied to the hole, so is that which is made upon the *retina* of these persons, when the chrystalline humour which is the *lens* of the eye is no longer fixed over-against the pupil. It is true, those two humours which remain, the glassy and aqueous, help the rays to unite, and a convex glass may in some measure supply the defect of the chrystalline humour. It would be well if this convex-glass could assist the eyes under a much more terrible distemper, in which, though they seem well and sound, the *retina* or the optic nerve being weakened and obstructed, cannot transmit any sensation to the brain of the images of objects, though they are clearly and distinctly drawn upon it. This distemper, which is called a *gutta serena*, occasioned the blindness, if not of the Greek, at least of the British Homer, which he inter-

weaves in his poem among the beauties of Paradise Lost, the battles of angels, and the pregnant abyss.

This picture then of the *camera obscura*, said the Marchioness, which seemed of no other use than to employ idle people, or such as have a taste for painting, is in reality of very great service to us, and in some cases even restores sight to the blind. Are we not obliged to Des Cartes for having rendered it so useful to us? Des Cartes, answered I, is very happy, to whom you would willingly be obliged for every thing. But in this case your acknowledgements are due to an industrious German, who laid the foundation of many things which others have since brought to perfection. He was the first who gave us a true explanation of Vision, which has always been a subject of speculation among philosophers; and consequently has had its share of ridiculous notions. For some among the ancients supposed certain rays, which, extending themselves from the inside of the eye to its superficies, pressed the air as far as the object to be seen; and this air finding some resistance from the object, made it perceptible to the sight: others affirmed that Vision was formed by the reflexion of the sight; that is, because rays flowed from the eye to the object, and were from thence reflected back to the eye; so that these gave it an exact information what the object was. Nor were there wanting some who affirmed that certain effluvia go from the eye, and meeting in their way with other effluvia of bodies, they link themselves with these, and turning back again with them to the eye, give the soul a perception of objects. And the most rational among them asserted, that extremely fine membranes formed of particles and atoms are thrown off from the surfaces of bodies, and have mutually the same disposition and

order, as there is in the surfaces of the bodies themselves from whence they proceed, and that these membranes, which they call *simulachra*, or images exactly resembling the bodies from whence they are sent, enter into the eye, and this is the cause of our seeing. And it is surprising to think that in such an age as this, such a country as England, there should be found any person * who, shutting his eyes against the light of things, would be again immersed in the profound darkness of unintelligible words, and assert that Vision is formed by means of the different degrees of the expansive force communicated from bodies to the eye through a *plenum*, and that the different modifications of it, as clearness, weakness, and confusion in the sight, arise from the proportion which these expansive forces have with the contractile ones of the optic nerves. However, all the moderns except this, (who, like him that wrote in these latter ages against the circulation of the blood, was necessary to give us a specimen of the infinite varieties and extravagancies of the human mind,) have rejected these

* Dr. Robert Green, fellow of *Clare-hall*, Cambridge, published in 1712. a book intitled the *principles of natural philosophy*, in which is shewn the insufficiency of the present systems to give us any just account of that science, and the necessity there is of some new principles in order to furnish us with a true and real knowledge of nature. In this book he undertakes to shew the unreasonableness of the greatest part of that philosophy hitherto received under the name of the *Corpuscularian*, and then proceeds to lay down the principles upon which alone he thinks it possible for nature to be explained. He farther endeavours to evince the incompetency of the present mathematics to furnish us with any just or adequate reasonings upon nature, and the necessity there is of some new principles in that science, which he has in some manner explained in the *geometria solidorum* annexed to this book, and from which he has been long assured that the squaring of the circle is not impossible.-----The celebrated Mr. Cotes professor of astronomy used to say that this book shewed the author to have had as extraordinary a genius as Sir Isaac Newton, since it must have been the effect of design to guard so effectually as he did against saying any one right thing throughout so large a treatise.

chimerical explications, the offspring of pride and ignorance; neither have they greatly esteemed the reasonings of those who thought that the effluvia proceeded rather from the eye, than from the objects; since it was more reasonable they should proceed from an animate than an inanimate substance; that the ears, the mouth, and the nose, were made concave to take these effluvia in, whereas the eye was made convex, and therefore proper to send them out. Notwithstanding all these fine reasons, opticians have reduced the eye to a perfect *camera obscura*, rejecting and extinguishing that light which the greater part of the ancients supposed to proceed from it. Indeed the august eyes of Tiberius must perhaps be excepted, who, as it is said, when he walked in the night, could for some time see as well as in clear day light, which is said to arise from his emitting certain sparks from them. You may say the same thing of any other person, who is considerable enough to deserve that an exception should be made in his favour.

It will be necessary for us, said the Marchioness, to look upon cats as considerable persons, and make an exception in their favour too. We shall willingly grant them that honour, answered I, only they must not take it ill if we say that the light, which seems to proceed from their eyes in the dark, serves only to give light to objects, and by this means the image may be drawn upon their *retina*: for Vision, as well as innumerable other things, is performed in the same manner in men as in brutes; or rather we may acknowledge ourselves obliged to those for that evidence which we have of the manner of its operation: for in order to demonstrate it, we make use of the eye of an ox, or some other animal, at the bottom of which when the

coats are taken away, if we place a very thin and transparent paper, we shall see the image of those objects, to which the eye is turned, drawn upon it and inverted, just the same as in a *camera obscura*.

This shews how very capricious our senses are. For instance, we say that there is heat in the fire no less than in our hands. Thus we confound one motion which is in the fire, and another that it raises in our hands, with the sensation of heat, which sensation is neither in the former nor latter. But we do not say that colour is in our eye as it is in objects, though without dispute the colours raise some vibration and motion upon the *retina*, and are painted upon it as strong and lively as they are upon the objects themselves. Thus we confound two things in the perception of heat, and only one in that of colours.

It appears, said the Marchioness, that we are much obliged to our senses in this point, for exempting us from one illusion at least. But do not they amply repay themselves by those many others to which they have subjected our sight? We see only one object, though it be looked at with both eyes, and see it upright, though it be drawn inverted upon the eye. You are a little too much prejudiced against the senses, answered I, and I must for this time undertake their defence. Is not the reason of all this violence which you express against Vision, because you had not the explanation of it from Des Cartes? Defend it, if you please, said she, without accusing me, and rescue it, if you can, from the charge of these two illusions which I allege against it. Would they not rather be illusions, answered I, if we were to see an object double which we know to be single, and that to be inverted which we

know to be direct? To-morrow we will enter upon a discussion of these two points, which Huygens, one of the great promoters of knowledge in the last age, thought beyond the reach of human understanding. To-morrow perhaps you may know more than that great man, but it is impossible for *that* acquisition to render you more charming than you are to-day.

D I A L O G U E III.

Several particulars relating to Vision, discoveries in Optics, and a confutation of the Cartesian system.

THE Marchioness felt the utmost impatience to be more learned than Huygens. She was not for losing a moment's time, but would have continued our discourses upon Vision, the next morning as soon as ever we were up. I told her that we must prepare ourselves with somewhat more ceremony for so high a degree of knowledge, and that it well deserved that we should at least wait till after dinner. In the interim not to lose time, she might learn how it comes to pass that the eye sees the objects which are without it, but cannot at all see itself. And from hence she might form a clearer idea of certain verses which no doubt must have been often addressed to her.

This was all the optics she could get from me in the morning. She waited for the afternoon with as much impatience, as an Initiate full of the expectation of being let into some profound mystery. In order to understand why we see only one object with two eyes, would you be pleased, Madam, said I, if I should tell you that in reality we see only with one eye, and that the other remains idle and at rest? You had better, said she, at once reduce us to a single eye, and then you will have no farther difficulty. I should be as well pleased, if you was to say that we walk only with one leg. You are more moderate, answered I,

than the Latin poet, who says, that women would be as ill-pleased to have but one lover, as but one eye. But this strange explication however was given by a grave philosopher, and resembles the pride of the Chinese, who fancy that all nations except their own see with but one eye, since both the one and the other are equally the offspring of ignorance. But this may serve to let you see what difficulties there are in solving the question we are now upon. Another made the optic nerves to resemble two lutes composed of various strings, which have an exact correspondence with each other, so that the two images of the object falling upon strings wound up to an equal height or a unison, the object must appear single. But all these fine and ingenious explications will not make you a better philosopher than Huygens. I believe that the true explanation of this difficult phenomenon, like many others in Vision, depends upon experiments. The senses of feeling and sight lend each other a mutual assistance in the formation of our ideas, just as our eyes and ears help each other when we learn a new language. The sense of feeling, which is much stronger than the sight, has constantly informed us that in the ordinary way of seeing, the object is but one, and by a long habitude we join the idea of one single object with the two sensations of it. In the same manner an object that is felt with two hands or two fingers at a time, notwithstanding the two sensations which we have of it, seems to be only one; and this is occasioned by those other ideas which we had conceived of it when we touched it only with one hand or one finger. If a button or a ball of wax be pressed with two fingers at a time in an unusual manner, by crossing the fingers together, it will appear double, just as objects do when we squint upon

them. In both cases the antecedent ideas of feeling are not so strongly united by a long habitude with these unusual sensations, as to make us join them with the idea of one single object.

Do you believe then, said the Marchioness with an air of surprize, that if a person had been long accustomed to press a button with two fingers crossed together, he would no longer feel it double? No certainly, answered I, for the very same reason that objects do not appear double to persons who are naturally squint-eyed. These by a long use acquire the same habit in their manner of seeing as we do in ours. We have a very singular and curious observation to this purpose, upon a person who by some misfortune had distorted and dislocated one of his eyes. At first all objects appeared double to him, till at length by little and little, those which were the most familiar to him, that is, those which he had the most experience of by feeling, became single, and in time all the rest, though the dislocation still continued. I may venture to affirm that, by virtue of this experience, Argus with all his hundred eyes did not see the fine heifer committed to his charge by the jealous Juno, at all more multiplied than Polipheme did his Galatea with only one eye.

You seem to exult mightily, said the Marchioness, in this experience which we gain from our touch: will it give you confidence enough to undertake by its assistance the solution of that question I proposed to you yesterday: How it comes to pass, that objects, which are drawn inverted upon the eye, appear direct in the mind? These experiments, answered I, extend farther than you perhaps imagine, and the ideas of sight considered with regard to those which we received from touch, are no more than four

strokes of a pen compared to a fine *relief*. We have the example of a statuary, who though he was blind, yet by the help of his feeling made tolerable good likenesses : one of the greatest mathematicians in England, that land of phenomena, and who could give you a much better explanation of optics than I can, was yet deprived of his sight so young, that he may be affirmed to have been born blind. This person is certainly much more wonderful than that learned Frenchman, who, without either voice or ear, undertook to learn music, and very much improved the greatest and most curious mysteries in that art. Feeling furnishes the imagination of this great philosopher with much clearer and more distinct ideas, than others receive from sight. What a pleasure would he have in making use of your fine fingers to explain the converging and diverging of the rays ? On the other hand, what could we learn, or what could we do without our feeling ? We should be incapable to judge of the situation, distance, or figure of objects, as Berkley had prophesied, who perhaps considered the metaphysics of Vision more than any one ever did ; and experience has verified this in some persons, who, after being cured of cataracts born with them, could not form any judgment, till the touch lent them its assistance ; without this, our eyes would continually tantalize us with a view of knowledge and pleasure, which we could never enjoy. The daily experiments then, that we make with our feeling, inform us that objects are direct, in the same manner as they teach us they are single, that they are placed in certain situations, at certain distances, and of certain figures. I believe Des Cartes is the only one who ever pretended to give an immediate explanation of this difficult phenomenon by a similitude. Sup-

pose yourself, said he, to have two sticks across each other, one in your right, and the other in the left hand, and to walk with your eyes shut about a room with these sticks before you. There is no question but you will think those things which you touch with the stick in your right-hand, and which by this means will make a pressure upon that hand, to be on the left; and in like manner whatever you touch with the other stick in the left-hand, you will affirm to be on the right. After the same manner the rays which proceed from objects to the bottom of the eye, crossing each other in the chryalline humour, those which press the *retina* on the right side will make you refer those points from whence they proceed to the left side, and those rays which press it on the left you will refer to the right side; and thus those rays, which press upon the upper parts of the *retina*, will make you refer the points from whence they proceed to the lower part, and those of the lower to the upper. And by this means the image, which is inverted upon the *retina*, makes you see the objects direct.

Indeed, said the Marchioness, this is very ingenious; why may not we confine ourselves to this without seeking any other, since it gives us an immediate explication of our phænomenon? Experience, answered I, unhappily informs us, that this is not an ingenious explication: a boy who stands upon his head sees every thing inverted, notwithstanding the images of external objects are pictured upon his *retina*, in the very same manner when he is in this situation as they are when he stands upon his feet. He has no other idea of high and low, than what regards his own situation; and when he is in this inverted position, he imagines the whole universe to be so too. Besides, the explication of Des Cartes supposes the idea of high

and low, right and left, which we can only have from feeling, to be antecedent.

It is our feeling, which by an experiment every moment repeated has constantly taught us to call the earth, towards which we find ourselves continually carried by gravity, *low*, those things which are contiguous to the earth, as the pedestal of a pillar or our feet, *below*; and those things which are distant from the earth, *above*; as our head or the top of a tree. The sense of feeling conveys these and the like ideas into the soul of a man born blind, with as much exactness as that of sight does the ideas of colour into ours. Now, if we suppose that veil which hides the visible world from his sight, to be taken away all at once, and consider in what manner he would judge of the situations of objects, we might from thence arrive to a clear knowledge of the manner in which we ourselves judge of them, since we have the ideas of high and low in common with him: he would certainly be more surpris'd at first opening his eyes, than the famous * Epimenides was after his long sleep of so many years, who remembered nothing which he saw about him when he walked, not even the place where he had been born and brought up. A new scene of ideas displays itself to him, a torrent of new perceptions rush upon him through this new avenue by which objects enter the soul. Amazed and overwhelm-

* A Cretan philosopher, when he was a boy, being sent by his father into the country, to fetch a sheep, he turned out of the road at noon, and repos'd himself in a cave, where he slept 57 years. After this refreshment he awaked and looked about for the sheep, imagining he had slept but a little while; not finding it, he proceeded to his father's country estate, where he saw every thing altered and in possession of another. He then returned to the city, and went to his father's house, where his younger brother, now grown an old man, at last knew him, and gave him an account of all that had happened. He was held in great veneration among the Greeks, who imagin'd him a peculiar favourite of heaven. He is said to have lived till 150 years old, or, according to others, 297.

ed with them, he finds himself transported, without knowing how, into another world. What a pleasure, what an extasy must this be, said the Marchioness! If novelty which always hovers about these things of which we have an idea, and is nothing more than an unusual combination of those objects we are already acquainted with, affords so much delight, what an infinitely greater pleasure must this man have in a world of things really new, and a new combinations of those ideas which he before had joined to those, with which the addition of another sense abundantly supplies him. But as human happiness is too often attended with some alloy, is it not possible for him to see something that would make him wish his eyes shut again when they were hardly open? He would have great reason to believe, that those objects would appear pleasing to this new sense, which had been so to the rest, and flatter this as agreeably as they had done those. But might not the event happen quite contrary to his expectation? and those objects, which had delighted his touch and hearing, prove very disagreeable to his sight? So that instead of increasing the number of his pleasures, this new sense would deprive him of the most sensible of them, and perhaps cruelly dissolve some pleasing tie which the others had closely bound.

It is true, answered I, that these senses do not always agree: how many persons do we daily see, who, convinced by sorrowful experience, that the reality of things does not agree with their outward appearance, find themselves too soon in possession of what they once thought they could never obtain soon enough? A blind man, answered the Marchioness, at least, while he is in love, should never desire to see; satisfied in the judgment of those senses which

represent an object agreeable to him, why should he ask that of another, which perhaps would at once condemn his choice, and, like reason, probably make him see his misfortune without giving him any assistance to avoid it? The only consolation, answered I, that this miserable person could have under the misfortune of sight is, that he would not be unhappy so soon as you perhaps imagine. How! said she, if the joy of receiving his sight did not entirely deprive him of all complaisance, would not the very first thing he desired to see be that person for whose sake he principally wished for the sight of his eyes? And when he had seen her, he would immediately, if she should appear disagreeable, perceive his unhappiness, if with regard to beauty, love did not render him a second time blind. He would enquire for her, answered I, would see her, and yet would not by that means know her again. This would be a miracle even beyond the power of love to effect; he would hear, if you will, the sound of those words pleasing to his ear, and still more pleasing to his heart, but he would not know the mouth from whence they proceeded. Yet more, he would be so far from distinguishing another, that he would not distinguish himself, his own feet or hands, from any assistance his new sight could give him, since he must be utterly ignorant of the connexions which the perceptions of sight have with those of the touch; yet this connexion is absolutely necessary in order for his knowing those objects again of which he had no idea, but what he received from senses of a nature very different from that of sight, and depends upon an experiment which he has never yet made. His own hands would be the first object he would learn to distinguish, by touching and looking upon them at the same time, and remembering that

such an idea of his feeling would agree with such another of his sight. When he had learnt this short lesson, love would the more easily conduct him to those experiments that would soon, either to his joy or sorrow, satisfy his curiosity, and we will conduct him to those that may content ours, which is of a more philosophical nature.

One of the first he would try, would be to lift up that hand which he has now no trouble to distinguish, and in doing this, he would perceive some change in the situation which he received of it from his sight, and the reason of this change is because the image changes its situation in the *retina*, in proportion as the hand is higher or lower. Guided by nature herself, he would diligently observe what sort of sensation he felt when he held his hand up, and whenever he felt the same sensation raised in him, either by the same or any other objects whose image would fall in the same situation of the *retina*, though unknown to him, he would conclude that object to be high, or in that situation in which his hand at first was. By this means connecting the old ideas of feeling, with the new ones of sight, he judges of the height or lowness of the object, of its being direct or inverted; and it is of no importance, whether the image of this object be pictured upon the *retina*, direct, or inverted, or in any other position.

External objects are *signified* to him, if I may use that expression, by certain sensations of light and colours, as the thoughts of the soul are to us by certain characters, not by virtue of any resemblance between the one and the other, but by means of an arbitrary, yet constant and perpetual, connexion which we have observed between them. And as when we are accustomed to any particular manner of writing, it makes no change in the order of the ideas which

these characters excite in us, whether they be written from left to right, as ours are, from right to left like the Oriental, or from top to bottom after the Chinese manner; so whether certain images be drawn direct or inverted upon the *retina*, it does not at all change our judgment of their situation.

The blind person, who has hitherto safely conducted us through this labyrinth, resembles each of us. We enter into light with our eyes shut, and probably do not begin to *see* till we have for sometime *felt*. Thus, Madam, you are indebted to the predominant sense of feeling, for this new explication too, and however little you may imagine it, you will find that to this you have had the greatest obligations through the whole course of your life.

I see very plainly, said she, that you interest yourself for the honour of the touch, much more than for that of Des Cartes; and it is not possible to propose any difficulty but you will be ready to give it a solution by the help of this sense. There are other difficulties, answered I, which I will give you a solution of without this, that you may see I have great plenty of explications. One of these perhaps may be to know what change must be made in the eye, in order for it to have a distinct view of objects placed at different distances. For as in the *camera obscura*, the rays which flow from objects that are near unite at a greater distance from the *lens*, than the rays of those which are more remote; so the very same thing happens in the eye, where the rays, which proceed from the pillars of this gallery, unite at a greater distance from the chrystaline humour, than those that come from these trees which are farther from it: what change then must be made in the eye, in order that when we look

upon these trees, after having looked upon the pillars, the rays which proceed from them may be united upon the *retina*, or in other words, that we may have a distinct view of them? The *retina*, answered she, must be brought nearer the chrystalline humour, just as the paper in the *camera obscura* is brought nearer the *lens*, in order to give us a distinct image of the more remote objects.

You have hit upon the true explanation, answered I; and some have affirmed, that certain muscles, which encompass the eye, are made use of to produce this effect, and press the *retina* farther back from the chrystalline humour, or bring it more forward, as different occasions require. These muscles have besides another office, and help us to lift up or depress the eye, to turn it to the right or left, and give it a certain oblique motion which Venus has the principal care of regulating. Others have supposed that the *retina* remains immoveable, and that the chrystalline humour approaches nearer to it, and removes farther off, or that the chrystalline humour only changes its figure, growing more convex for near objects, and less so, for those which are distant; and others have affirmed, that each of these happens at the same time, which will produce the same effect, as if the *retina* approached to or receded from the chrystalline humour; but you had better suppose this latter, because it is easiest to imagine. For every distance then, there is required a new conformation in the eye, and because this cannot be effected without motion, and a certain effort, some are of opinion that the eye informs us of the various distances of objects by a certain natural geometry. But this way of judging, especially where very distant objects are concerned, is extremely

uncertain, as indeed almost all the rest are which have ever appeared upon the stage of philosophy.

But however this be, there are some persons who cannot bring their *retina* so near to the chrystaline humour as is necessary, in order to give them a distinct view of distant objects. There are others, who, on the contrary, cannot press it back far enough, to make objects which are near appear distinct. The first of these, who are vulgarly called short-sighted, are by opticians named *myopes*, and the second, commonly called long-sighted, *presbyta*: these may be considered as the extremes betwixt which that sight, which is called just and perfect, stands. Notwithstanding the honour of being distinguished by names drawn from Greek, these persons could not help perceiving they had a defect in their eyes, which led them to seek for some remedy: the *myopes* in order to have a distinct view of distant objects, and the *presbyta* of those at hand. These last found relief in convex-glasses, which, applied to the eyes, removed their defect; for these making those rays to become converging, which would without their assistance have fallen diverging upon the chrystalline humour, unite them at a less distance than they would otherwise have done; and the image of those objects which are opposite to the *lens*, is drawn distinctly upon the *retina*. The *myopes* found their remedy in concave glasses which disperse the rays and make them diverge; contrary to the convex ones, which make the diverging rays become converging. These concave-glasses then give a disposition to the rays, as if they came from a nearer object than they really do, and applied to the eye of a *myope*, they in a certain manner transport the distant object to a nearer situation, and thus a distinct image of it is drawn upon his *re-*

tina; for there is nothing more required to give short-sighted persons a distinct view of any thing, than to bring it nearer to their eye.

It was very happy for them, replied she, to find these glasses as safe and easy a remedy perhaps as ever the art of physic itself invented. But what did they do before they were found out? Till the thirteenth century, answered I, when these glasses are supposed to be invented, the Myopes were obliged to approach near to distant objects in order to see them distinctly, hoping perhaps that an advanced age, when according to the common opinion the *retina* approaches nearer to the chrystalline humour, might give them some relief from this inconvenience; but indeed this is a remedy much worse than the disease. The Presbytae, on the other hand, were obliged to remove a great way off, without any hope of ever seeing the objects situated near them distinctly, if they should at any time have a curiosity for it, and they continually tormented their eyes with plaisters and *collyria*, without gaining the least advantage to their sight. I think the condition of these last, said the Marchioness, much more to be pitied than that of the first, both because they cannot flatter themselves with the least hope of growing better, and because they lose a great deal more in the conversation of ladies than the Myopes do. How miserable must have been the state of a poor Presbyta, who could never have a distinct view of his mistress, unless he breathed his sighs ten foot distant from her!

These are not so much to be pitied, answered I, as you imagine, since this defect generally happens in an age when hope and the conversation of ladies naturally desert us. For this is a defect of old men, as the very word Presbyta

imports. But there are other defects and infirmities of the sight incident to all ages, which are never placed in the number of defects, for the very same reason that the folly of being more solicitous for the future than the present, and by that means continually procrastinating our happiness, is never reckoned among the list of follies, namely, because it is common and universal. Philosophers, who have a quicker perception of things, have discovered and sought remedies for these defects; one of which is, that very small objects are invisible, however near they may be placed to the eye; the other, that very distant objects cannot be discerned, even if they are of a very great magnitude. These are inconveniences which you see are not at all felt by the vulgar, but reserved for the curiosity and nice perception of philosophers. The reason of both defects is, because the image of very small or very distant objects, painted upon the *retina*, is not big enough to be perceived by the eye, notwithstanding the proximity of the one, or extraordinary magnitude of the other. The remedies invented by philosophers to supply them are certain instruments, whose only business is to magnify this image and render it perceptible to the eye, by means of various combinations of glasses, or by one alone. Those which are made use of to discern distant objects, are called *telescopes*, and those which help us to a sight of exceeding small objects, *microscopes*. We are obliged to each of these for an infinite number of discoveries, which could never have been made without them. The heavens are the principal object of the *telescope*, from whence it has furnished philosophers with more curiosities than ever Columbus could bring from America to enrich the cabinets of the naturalists. For not to speak of the hills and vallies which they have

discovered in the moon, the satellities of Jupiter so very useful to geography, those of Saturn with his *ring*, it is to those *telescopes* that we owe our discovery of the spots in the sun, Jupiter, and Mars, which are necessary in order to determine the periods of their revolution round themselves, and by the assistance of these, astronomers have given us so exact a map of Venus, that they are as well acquainted with her mountains in heaven, as the geographers are with those upon earth. They have discovered that this planet has an increase and decrease, that it is at one time half, at another full, in short, that its appearance and phases exactly resemble those of the moon, as it had been conjectured by the celebrated Copernicus, before the invention of the telescope. These give the celestial bodies their proper distances, and have shewn us an infinite number of stars, unknown to the antients, discovering so great a quantity in the milky-way, as is sufficient to supply ten or twelve worlds besides our own. In short they have given us a true system of our world, by extending its confines to infinity; so that if a poet, to flatter a nation which had made a greater progress in the conquest of the world, than in the knowledge of its frame, could say, that when Jupiter turned his eyes upon our earth, he could see nothing in it that was not subject to the Roman empire, we may affirm with greater truth, that if he looked upon the heavens, or at least the *solar vortex*, he could not see any thing in it, but what is the discovery and conquest of the telescope.

You represent these telescopes to me, replied the Marchioness, under such sublime images, that I am afraid the microscopes will make but a very insignificant figure, when compared to them. There is, answered I, a very remark-

able difference between them, in which I believe the last have the advantage. The telescopes, it is true, by discovering to us the hills and valleys in the planets, their stations, revolutions round their own axis, that is to say, their day and night, the moons that from time to time supply the absence of the sun; in short, by representing them to be of the same nature as our earth, have furnished us with materials to people these vast and immense bodies which were before uninhabited, stood neglected in a corner of the universe, and were believed to exist for no other end than to please our eyes. But microscopes have made us in reality see an infinite number of animals, of which we had not the least knowledge before, in things which were not looked upon as very proper to afford them a habitation. Not to say any thing of the discoveries in anatomy and natural history, which we owe to these glasses; aromatic infusions, a drop of vinegar, are peopled by so prodigious a number of little animals, that Switzerland and China would appear empty and uninhabited, when compared to them. The microscope, said she, is the compass of philosophy; each of these have given their assistance to the discovery of new worlds; the only difference is, that the microscope has lent its art to people, and the compass to destroy.

It is very wonderful, answered I, into what innumerable animal worlds philosophers have penetrated, under the guidance of this compass. It is an amazing thing to reflect upon the minuteness, art, and curiosity of the joints, bones, muscles, tendons, and nerves necessary to perform the swift motions of the smallest microscopical animals.

These discoveries shew us in how little a compass all art and curiosity may be comprized, even in a body less than

a small grain of sand, and yet as complete, as exquisitely formed, and as finely adorned, as that of the largest animal. Their multiplicity is no less surprising than their extreme fineness. A drop of the green scum upon water, no bigger than a pin's head, will contain no fewer than an hundred; which, far from being confined in that narrow extent, play about in it with all the freedom imaginable. The eye of a butter-fly will contain more than twenty-four millions of eyes; and the wonder is still greater, when we come to consider the organization of their fine and minute parts. If the eye of a fly, which seems to be a little misformed protuberance, be looked on thro' a microscope, it appears to be only a composition of thousands of little eyes, just as some nubilous stars, on being viewed with a telescope, appear to be a cluster of innumerable other stars. In some insects there have been counted no less than thirty four thousand of these little eyes, which, notwithstanding their extreme fineness, had each of them a chrystalline humour as perfect as ours.

Why are not our eyes, said the Marchioness, of so fine a texture? This question, said I, has been already answered.

For this plain reason, man is not a fly.

Say to what use were finer optics given?

To inspect a mite, not comprehend the heav'n.

But in fact, there are some insects, that with these microscopic eyes can see as far as the greatest part of men. The bees, an industrious species of flies, from whose labour we reap so great an advantage, can direct themselves safely to their hives, though at a mile distance, when they return laden with the sweet treasures of the spring. It appears that what nature has given us in reason, she has de-

nied us in exquisiteness of sense. Pigeons, the couriers of the east, such as that which brought news from Egypt to Jerusalem, when it was besieged, of a quick and powerful succour, or that beautiful one presented by Venus to Anacreon in exchange for one of his odes, and which, for having so often carried his letters to Bathyllus, deserved to sleep, and be sung upon that lyre which could resound nothing but love; these flying couriers, I say, being let loose by the person, who has a mind to send home news of himself, ascend a prodigious height, and from thence, though at a very great distance, can see their native country, and safely direct their flight to it, without the help of either stars or compass. Moles seem to be quite contrary to these sharp-sighted couriers. Nature, said the Marchioness, has perhaps made them amends some other way. It is probable, that she has constituted the condition of animals pretty near as equal as that of men. Their eyes, answered I, are certainly not to be envied: they are so small, and covered with hair, that it seems as if nature had given these tenants of darkness, eyes to see the light, for no other end than to fly from it. These animals are not formed to contemplate the wonders of the microscope, nor see in one drop of water so many **thousands** of animals, organized with that exactness which is necessary to enable them to see, move, and nourish both themselves and other little animals, which repay them the mischief they do to us, and to contain within them an infinite number of still other little animals of their own species, much less than they, and which only wait to unfold themselves to make their appearance in the microscope. These observations open a scene of innumerable other worlds of animals unknown before, which, notwithstanding their extreme and

surprising smallness, have their greater and less, their elephants and ants, just as ours has; the only difference is, that our ants become elephants when compared with their largest animals, or rather are as the immense distance of Saturn from us, is to the extent of a grain of sand.

Indeed, said the Marchioness, this new scene of pigmy worlds gives me as much pleasure, as that other immense and gigantic scene of *vortices*, or suns diffused over the whole universe. The little has its beauties as well as the great, or rather, answered I, there is no great or little, but with regard to ourselves. Gulliver, who could destroy the Liliputians like so many flies, was among the Brobdinagians kept in a cage like a Canary bird, or for an ornament upon the chimney, like a Chinese pagod. It is principally the microscope, and that infinite number of pigmy worlds discovered by it, which has rectified our ideas of great and little so much, that I am persuaded, that the consideration of this incredible and surprising smallness, which it has rendered perceptible to our senses, has served to soften and familiarize to mankind another consideration which is the master-piece of human understanding, and directly leads us to the subversion of great and small. This is the consideration of infinitely small quantities, which has made so great a noise in the learned world, and which you perhaps may have heard of. The meaning of this expression is, that there are parts and quantities in extension, so exceedingly small, that they may be reckoned as nothing when compared with our measures, as the fathom, foot, inch, and the like. So that if one of these quantities was added to the extremity of a line, for example, of a foot, it would not increase the length of it, nor decrease it if it was to be taken away. And the

mathematicians affirm, that in these quantities, infinitely small with regard to the ordinary measures called *differences*, there are innumerable orders and gradations, so that a quantity, which is infinitely small compared with the order of our common measures, is infinitely great when compared with an inferior order of infinitely small quantities, and so of the rest. The most enormous sizes we have may become infinitely small when compared with an order of greatness infinitely superior. To how small a size is reduced the colossus of Nero, or that of Rhodes, when compared to mount Athos, carved in the shape of a man, and holding a city in one hand, and pouring out a river in the other? Compared to Milton's Satan, Virgil's Fame, the formidable Shade of * Camoens, that Polepheme of the ocean, which appeared to the Portuguese sailors, hid its head in the clouds, and its feet in the unfathomable abyss of the sea; or in short, what would all this appear to that angel seen by Mahomet in his mysterious night, whose eyes were seventy thousand days journey distant from each other? It is computed that if he were of a human shape, there must be the distance of forty thousand years journey from his head to his feet.

Probably, said the Marchioness, there must be a great number of telescopes and speaking-trumpets in the Turkish paradise, in order for the Mahometans to be able to see and converse with these diabolically great angels of theirs,

* Camoens, the famous Portuguese poet, in his *Lusiada*, the subject of which is the discovery of the East Indies by his countrymen, conducts their fleet round the coast of Africa, and as it sails in sight of the Cape of Good Hope, he introduces a formidable spectre walking in the depth of the sea, its head reaching to the clouds, its arms extended over the waves, and its whole form surrounded with clouds, storms, winds, thunders, and lightnings. This spectre is the guardian of that foreign ocean which no ship had ever passed through before, complains of his being obliged to submit to fate, and the bold undertakings of the Portuguese, and foretels them the misfortunes they must undergo in the Indies.

There are, answered I, the same orders of infinites in the succession of time, as there are in extension. An hour, a minute, a second, are of an infinite duration compared with periods of time infinitely shorter. How enormous must the duration of the Roman empire seem to an animal, which in the space of five or six hours is born, grows up, produces one like itself, becomes old, and dies? What we should call the flight of time, would seem to this insect an eternity. But what are these durations of empires, this long succession of kings, emperors, consuls, and these tedious sieges, when compared with eternity? Is it more than a point in which we live, fight, raise such great commotions, and make so much noise? The Orientals say, there is a god that governs this world, who dies at the end of a hundred thousand years, and this space another superior God esteems but as a minute. And yet all these examples give us but a very imperfect idea of infinity. This consideration, the utmost stretch of the human mind, which we owe to Sir Isaac Newton, and which entirely overthrows all the ideas of absolutely great or little, was the foundation of the famous arithmetic of *fluxions*, or infinitely small quantities, which transplanted geometry into a province entirely new. Here it made so rapid and great a progress, that all it had done before seems nothing, and here by the assistance of new discoveries it produced such strange paradoxes, that they have in some measure clothed truth in the agreeably surprizing dress of fiction: and what is the most remarkable in the new geometry is, that by considering the properties, relations, and habitudes between infinitely small quantities, it arrives at the discovery of common and finite measures, which are the object of our enquiries.

If the sagacity which we so much admire, said she, consists principally in uniting those things in the mind, and finding their relation, which seem to be in their own nature disjoined and separated, what an unlimited understanding must Sir Isaac Newton have had to find the relation, and in some measure unite these quantities, disjoined and separated from each other by the immense tracts of infinity, where the human imagination quite loses itself! And, continued I, the consideration of these infinitely small quantities that we neither see, nor can conceive, which appeared only fit to perplex geometry, have in fact served to render it more easy, and reduced it at the same time to such general rules, that the most sublime and abstruse truths, in this science, are at present nothing but one of the infinite consequences which is lost among the croud of those that are deduced from the stroke of a pen; and, if you please, in a circle of ladies; truths that once required an Archimedes, with all that attention of thought which was necessary to make a person insensible of the noise of a town taken by storm, and be knocked on the head without perceiving it.

This consideration then of infinitely small quantities, said the Marchioness, and the observations of the microscope, which have rendered it more familiar and common, have given a very strange turn to geometry. It now treats of quantities, which from their extreme smallness were once utterly unknown, and does not at present disdain to enter into the company of ladies. A province with which I believe it was once as little acquainted, as with that of the infinitely small quantities. It is true, answered I, that geometry is rendered so very familiar, as sometimes to suffer itself to be treated by a hand as beauteous as that of

Venus of Medicis. But it is true likewise, that it sometimes resumes its fierce and savage disposition, especially when it is attended by that train of consequences, deduced from the stroke of a pen, as I before mentioned to you; and goes back into solitude and retirement.

Mankind however, said she, ought to think themselves greatly obliged to the microscope, for having contributed to soften and familiarize a thing whose very name alone inspired so much terror. Mankind, answered I, are not very often guilty of the sin of gratitude, and, as that polite philosopher, who is to instruct you in the motion of the earth, observes, there are some who make no scruple to treat the study of anatomy, which perhaps may have saved their lives, as a useless thing. You may judge from hence, whether it be probable that mankind will be grateful at the expence of so much consideration as is necessary in order to know whether the microscopes have contributed any thing to familiarize the calculation of infinitely small quantities, what this calculation is, and what uses it may have; all which things are necessary to form a well-grounded and rational gratitude. An English frier, called Roger Bacon, who lived in the thirteenth century, and had a general knowlege of the effect of the *refractions* of light by a *lens*, and was besides acquainted with many other things which are commonly believed to be the production of much latter ages, such as the invention of gun-powder, the reformation necessary to the calendar, and was sensible of the false method of study at that time in fashion; this very man, worthy of a statue and immortal honours, was ill treated, persecuted, kept prisoner for many years, accused as a conjurer and wizard, and of holding intelligence with the Devil, in order to effect what required only su-

perior parts, and a free use of reason; and all the honour these inventions, which we at present so greatly admire, met with at that time was, that the inventor was judged worthy to be burnt alive. It is true, that at present the learned cannot admire the depth of understanding, and the quick penetration of a man, who, in so barbarous an age as the thirteenth century, thought in a manner that very few of his species do even in this age, as enlightened as it is. But what gratitude is this to persecute, imprison, and almost burn him when living, and at the end of five centuries, to republish and give him the highest encomiums? Is not this like deifying Homer after his death, when he had been suffered to starve with hunger, while living? The telescopes, which have been the cause of so many fine discoveries in the heavens by their assistance, did not by that means at all advance his fortune here upon earth.

It is surprising, said the Marchioness, to see the folly and caprice of mankind. In some cases they are so extremely fond of novelty, as to adopt the most extravagant things merely on that account. This, we see, happens, every day in the fashion of dress, sitting, taking snuff, and even sneezing. At another time, novelty is an objection to the most useful and well contrived schemes. Are our judgments never to be guided by reason?

The wise men of past ages, answered I, appear to us like the moon just on the edge of the horizon, and those of the present time, like the same planet, when it is a great way above it. The image of the moon painted on our *retina*, when she is at the horizon, is less than when she is elevated a great way above it, at the meridian, for example; and this is occasioned by the distance of the moon from us, which is greater in the first case than the second.

Yee notwithstanding this, we imagine her to be much bigger at the horizon than at the meridian. This mistake proceeds from the interposition of other objects, as trees, houses, tracts of land, sea and sky, which are betwixt us and the moon, when at the horizon, but not when she is at the meridian, for in that situation she is left entirely to herself. Now as the objects placed betwixt us and the moon, make us imagine that she is more distant from us at the horizon, than the meridian, they are the reasons too why we imagine her to be bigger, because the apparent bigness of an object depends on the size of its image on the *retina*, joined to the judgment we form of its distance; so that the image being always of the same size, the object must appear so much the greater, as it is judged to be more distant. Hence it is, that actors, when they come from the bottom of the theatre, appear to us like giants, the perspective and the delusion of the scene making them appear a great way off. Why should those objects placed betwixt us, and the moon when at the horizon, said the Marchioness, interrupting me, make us imagine her to be farther off from us, than when she is at the meridian? I should think they would rather make her seem nearer, for in that situation she appears to touch them, and it seems probable she should appear at the same distance from us as the objects themselves: whereas at a greater altitude, we see her placed in the sky, and consequently judge her to be at a great distance. We know, answered I, that the moon in both cases is in the heavens, or rather that the heavens themselves are an immense vault, to which our imagination always refers the heavenly bodies. But the sky itself seems much more distant from us at the horizon, than when we look directly above our heads, so that it ap-

pears to us as a compressed vault. Between us and that part of the heavens which is over our heads, there is nothing to regulate our judgment of its distance; whereas at the horizon the long series of intermediate objects helps us to form the distance, and make us judge it very great. Hence it comes to pass, that distances appear much greater upon a plain than a mountain; because the equality of the plain lets us see every thing that is placed between us and the distant object, which the inequality of the mountain will not suffer us to do.

In the famous picture of Correggio, at Parma, so ill copied by the chisel of Agostius Caracci, who was otherwise a great man in his profession, an artful series of hands, heads and feet, place a distance between St. Catharine and the head of the Madona, so sensible, that you would imagine it might be measured by the touch, and which, added to the other beauties and graces of art all united there, render it a master piece of painting.

Now, to finish our optic comparison, the antients appear to us through a long series of emperors, kings, archons, consuls, and many other objects, which greatly magnify them: but we see the moderns alone, separated and left entirely to themselves like the moon at the meridian. Hence it is, that the manner in which the antients buttoned their coats, will be a subject of admiration to the learned; whereas there will be only two or three men of good sense to applaud any useful invention of a modern, who has the misfortune to be born in the same age with ourselves, and not to be distinguished by a name with a Greek termination. And this is the way in which a great part of those who value themselves upon their learning, think. Horace very finely satirized this folly in the time of Augu-

flus. So true is it, that a wrong turn of thinking is the growth of every age.

But would not the Chinese, said the Marchioness, be gainers by the immense distance between them and us? And may not a million of miles produce the same effect as many successions of kings and consuls? They are certainly no losers by it, answered I; but however, those very persons who most idolize this nation, which in the midst of observators and astronomers could not produce a tolerable almanac, agree that we are superior to them. This confession perhaps is the effect of natural self-love. The Chinese form a nation entirely separated and different from us; whereas the antients are as it were of the same family with ourselves, and we regard them as our ancestors. And after all, some few sorry thousand miles can never be equivalent to a list of archons or consular Fasti. In short it is here, as in the compositions of the theatre, in which people suffer themselves to be much more easily deceived in what regards the customs and manners of the antient Greeks and Romans, than in those of the Turks, or Japonese.

Another instance in which this comparison holds good, between the antients and the moon at the horizon is, that she appears the greater to us upon the account of her being less resplendent there, than when she is at the meridian. Those objects which are the farthest off, are the least illuminated. So that if two objects, are of an equal size, the least illuminated will be thought the most distant, and consequently the biggest. Hence trees and houses appear greater to travellers in the twilight, than in full day; the sun seems bigger when seen through a cloud, and objects must generally appear greater in England, than they do

in Italy. The sun, after the death of Julius Cæsar, continued pale and languid for the space of a year, and according to the expression of an elegant poet, threatened that guilty age with an eternal night. If the Romans had dealt in observations, I do not doubt but they would have informed us, that he appeared likewise bigger than ordinary. Objects then, said she, are magnified by the mists of antiquity: many of those great philosophers, whose names now pass for a proverb, were perhaps no more in their own time, than the regent of a college, or the lecturer of an university. Those, answered I, who are the most devoted to them, are the most likely to see them greatly magnified: for, as the finest and most judicious verses in the world inform us, fools *admire*, but men of sense *approve*; and every thing appears magnified to dulness, as objects do when seen through a mist. I should not at all wonder, if some profound admirer of the Greeks should prefer the Epicurean explication of vision to that of the moderns, for this only reason, that one is more antient than the other.

What explication is this, said the Marchioness, for I do not remember that you have mentioned it to me before? It was the last I spoke of, answered I, when we were talking yesterday about the explications which the antients have given of sight. This supposes that certain shadows, or images fly off from bodies, by whose means we see. Though this may seem reasonable enough to some persons, yet there arises a great difficulty to explain how it happens, that when we are in the dark we see objects that are placed in the light; but when we are in the light, we cannot discern objects placed in the dark: since according to this explication of the Epicureans in both cases, there are sha-

dows which fly off from the objects, and raise in us the sensation of vision. Lucretius calls a certain lucid and subtile air to their assistance, which, entering into the eyes when they are in the dark, disengages them from the more thick and black air that obscured them, and by this means opens a passage to the shadows which from objects placed in the light proceed to the eye. When objects, on the contrary, are placed in the dark, the thick black air fills the eyes, and by this means, denies a passage to the shadows which are transmitted to the eye from those objects.

The image of any object, said the Marchioness, cannot be drawn upon the *retina*, unless there are rays transmitted from the object to the chrystalline humour, just as in the *camera obscura*, an object, in order to have its image painted upon the paper, must transmit rays to the *lens*. If then the object be placed in the light, and we in the dark, its image will be drawn upon the *retina*, and we shall discern it; but if the object be placed in the dark, it cannot transmit any rays to the chrystalline humour, there can be no image drawn upon the *retina*, and consequently the object cannot appear to our sight. But I do not see what relation there is between the thick or subtile air of Lucretius, and these images. It is true, answered I, that this air has nothing to do with the image on which vision depends, but it has a great relation to these shadows on which depends the *honour* of the Lucretian philosophy. And what is there in the world, that a philosopher, embarrassed in the explication of a phenomenon, does not lay hold on? But since you have so well explained this, I will venture to propose to you another, which you must often have observed; it is, that in going from a very light place to one which is much less so, and may even be cal-

led dark when compared with the other, the objects in this place are at first not at all discernible, but by degrees they begin to appear, and after some time are seen very distinctly. This often occasions great mistakes in society, which are very soon found out, and repented of. Any one, for instance, going into the chamber of a lady, who, either because she is indisposed or fancies herself to be so, likes to sit in the dark, may take one person for another, and a fine compliment be wrong addressed, and the error afterwards appear to the great confusion of the person who had been at so great an expence of wit in forming it.

This phenomenon, said the Marchioness, smiling, has very important consequences, and merits the utmost attention. But I must confess, it appears to me a little more perplexed than the first, and I do not know how many degrees of subtilty in the air Lucretius would require to explain it by. Yet the explication of this phenomenon, answered I, depends entirely upon a thing which you must very often have observed with the utmost diligence. Have you never remarked that there are no eyes, not even your own, but appear much finer by night than in the day? I agree to this, said the Marchioness, that we may not spoil our observations by compliments: But does it not proceed from hence, that the night does not shew the defects of the face so much as the day, and therefor the eyes too must be gainers? The true reason of this phenomenon answered I, is, that in the dark, the pupil is more open and dilated, which makes the eyes look blacker and brighter in the night than in the day, when the pupil is more contracted. How many eyes have triumphed in the evening and gained conquests which they lost the very next morning at the approach of the sun! The pupil is contrac-

ted in very light places, in order that it may not admit too great a quantity of rays, which would only serve to do it hurt. On the contrary, it is dilated in the dark, enough to admit such a quantity of rays as are sufficient to cause vision. The reason perhaps, why some animals never creep out of their holes till evening is, because they are not able to contract their pupil so much as is necessary to hinder the light of the sun from injuring their eyes. When we go therefor from a light place, to one which may comparatively be called dark, the pupil, being at first very much contracted, does not admit such a quantity of rays into the eye, as is sufficient to raise the idea of vision. The pupil afterwards begins to dilate itself, and we begin to see. And as this dilatation is made by degrees, so we discern the object by degrees still clearer and clearer, till at last, when the pupil desists from dilating itself at a certain point, we afterwards continue to discern the objects with the same degrees of clearness.

You have not given me the least time to think on this, said she. Who can tell whether I might not have found out this explication, which now at least does not appear at all difficult to me? It is sufficient for you, Madam, said I, to have explained one phenomenon, and seen the difficulty of another. A very great exploit, truly, said the Marchioness with some emotion, to see difficulties and not be able to resolve them. It is a very great honour indeed for a general to besiege a town and not to take it! No, said I, but it is sometimes an honour for him not to undertake the siege at all. The first step to wisdom is to cease from folly, and the first point of learning not to be too arrogant, but perceive our own weakness. This is a point of modesty very little practised by those gentlemen who with the

vulgar gain the reputation of philosophers, merely by their declaiming in assemblies and coffee-houses, against the antient philosophy which they know nothing of but the name, stigmatizing those who profess it with the title of Ergotists, and having read perhaps some preface or literary journal. Such sort of persons never doubt of their knowlege, but explain and pass a decisive judgment upon every thing. These are blind men who would walk in a garden with the same freedom as other people, but the first basin they come to, fall in. There is an observation which the more it is examined, the truer it will appear, that nothing in the world is so difficult to be met with, as common sense.

I perceive, said the Marchioness, that I have some right to call myself a philosopher. I have my head full of vortices; I form light by the pressure alone of the globules of the second element, and colours by their rotation. I have renounced the most agreeable qualities, and retain nothing but a little extension, and infinitely small quantities. I am not certain whether the world appears the same to all eyes: I explain one phenomenon, and see the difficulty at least of another; I think I have contempt enough for the antient philosophy; and after all this, I hope it will not be said that I am not wiser than I was. Do I want any thing else to make me a complete philosopher? — Yes, Madam, answered I, perhaps you should have a little less beauty, or make a better use of it. But you do not perceive that the philosophy you are so fond of needs a reformation, and I wish this reformation might be the last.

What, said she with some emotion, will you tell me that Vision is not performed in the manner you have

hitherto explained it? This is plainly betraying me, and affirming upon your word, what afterwards appears not to be true. No, no, Madam, answered I, be not uneasy, I am not of a character to propose to you things differently from what they are. Vision shall remain untouched; that abjuration, which you have generously made of the roses and lilies in your cheeks, shall stand good and be ratified in form. The doubts you are under, concerning the different appearance of objects in different persons, shall still continue to be reasonable, and your preferring the moderns to the antients, shall still be compatible, and remain as it is founded on the very best reasons. The reformation I spoke of will affect nothing but the globules of light, and the manner in which they excite in us the sensation of colours. You may hereafter if you please regard the system of vortices, as one of the finest and most entertaining philosophical poems in the world, which is the idea under which I at first proposed it to you. This is absolutely disconcerting my ideas, said the Marchioness. I would willingly look upon this system as something more than a fable, were it ever so fine a one. I cannot think of changing any thing in the globules of light, which with so very little trouble supplied me with the most agreeable colours. If I once quit these, who knows how much pains, and how great an apparatus it will cost me after this to make even a sorry metzotinto?

It will cost you no more, answered I, than it did with your globules. This reformation was produced by father Malebranche; one of the greatest and most illustrious Cartesianes that ever appeared in the world. The authority of so great a name may let you see, how very necessary this reformation was, and you may moreover be sure that the simplicity which has always formed the delight of this

fect cannot fail here. This simplicity is an idol, to which they sacrifice every thing, even truth itself sometimes, that truth, which an antient called the citizen of heaven, and companion of the gods. But before I proceed to this reformation, it will be proper to lay before you the great difficulties which must make you for ever renounce your globules. This system, like Hercules in the fable, had very great difficulties to encounter with from its very birth; but perhaps it did not overcome them with equal honour.

Some objected, and with great reason, that according to those laws assigned to the vortices by their inventor himself, as the stars are not composed of the subtle matter, but of that of the third element, instead of being luminous, they would be covered with an opaque crust; and even if they were luminous, the contrary and equal pressure of the vortices would not suffer us to see them.

However weighty these objections might be, they would not be able to shake the faith of the steady Cartesians. But this, which I am now going to mention, appears an indissoluble gordian knot, even to the most zealous and ardent among them. You have this formidable enemy of the Cartesian philosophy in your own house, nay, in the very gallery where we are, and you do not perceive it. This painted wall is an adversary that makes war against the system you are fond of. Deliver me from this perplexity, I intreat you, said the Marchioness, or I shall erase the picture. You have a mind to make me quarrel with my own house for presenting me with such detestable objects. No, Madam, answered I, smiling, that is not my intention; I would rather have you persuaded that every corner of it is since yesterday become philosophical.

Let us fix upon one point in the air to which your eye

and mine may be equally directed while we are both looking at the same time upon different parts and different colours of this wall. Do you, for instance, place yourself at this pilaster, and look upon the red on the vesture of Achilles. I will stand at the window, and look upon the blue of the sea; so that while you are looking at the red and I the blue, our eyes may each be directed to the same point of air. It is certain, that two rays will pass through this point, one from the robe of Achilles, and the other from the sea. These rays you know are nothing but two series or strings of globules immediately touching each other, the one continued from the robe of Achilles to your eye, the other from the sea to mine. These two strings of globules intersect each other in that point which we have fixed in the air, and consequently in this point there will be one globule common to both strings. Do you understand all this? Yes, too well, said she, and I begin already to tremble. In order for these globules to excite vision in us, answered I, the pressure of those contained in that string, which comes from the robe of Achilles, must be continued from thence to your eye, and the pressure of those contained in that string which comes from the sea must from thence be continued to mine. Now that globule, which happens to be in the point of air, where the two strings intersect, and which is common to each of them, must at the same time press towards your eye and mine, which is utterly impossible if the globule be hard, as Des Cartes supposes it to be; because the close union of the parts of such a body can never suffer it to press at the same time towards two different sides. But this is not all. — And yet this is sufficient, said the Marchioness, to demolish my globules. The very same globule, said I, as hard as it is, must have

at the same time two different rotations, one to excite in you the idea of a red colour, which is communicated to the whole string that comes from the robes of Achilles to your eye, and the other to excite in me the idea of an azure colour, communicated to the whole string that comes from the sea to my eye. But the difficulty will be still greater if we suppose other spectators to be placed in this gallery, who all direct their eyes to the same point in the air, as we have fixt upon, and other rays to pass through this point, some of which should convey the golden colour of Achilles's hair, that Minerva lays hold on in order to calm his destructive and impetuous rage; others the green of this meadow, and the innumerable other colours which variegate the picture. You see then, that supposing your globules, such as Des Cartes has made them, it would be impossible for us to see what, however, we really do see. I understand this but too well, answered she; but I beseech you, for the love of philosophy, never mention these globules to me again. I am resolved to think no more of them since they have so shamefully yielded to the very first difficulty. They seem to resemble those unexperienced lovers, who at the first repulse think of a retreat. But pray let me see what your reformed Cartesian Malebranche substitutes in their place; for I am persuaded he will be able to make a better resistance.

Malebranche, answered I, entirely rejects these solid globules which you have forbid me to mention, and substitutes in their place certain exceeding small and fluid vortices composed of an ethereal and very subtile matter, which fills all the great vortices, as the great vortices which are the seats of stars and light do the universe. These little vortices, by that power which they have of dilating them-

selves, keep a mutual equilibrium in their respective vortices, just as the great vortices do in the universe. In this system of Malebranche, light is nothing but the undulation or vibration of the vortices, occasioned by the vibration of the luminous body which is always repelled in the same moment that it impels; and the greater or less force of the light depends upon the greater or less force of these vibrations, just as colour depends on their greater or less velocity. For instance, if these vortices should raise fifty vibrations upon the optic nerve of the retina, in any determinate space of time, it would give us the idea of a certain colour; if in the same time there should be a greater or less number of vibrations raised, we should have the sensation of a different colour. Malebranche ingenuously confesses however, that he was not able to assign what determinate degrees of quickness were necessary to form different colours in particular. A confession so much the more ingenuous as it is extraordinary in a philosopher.

This system of light and colours has a very great affinity with that of sound, with this difference only, that air is the vehicle or channel of the one, and ethereal matter or the vortices composed of that matter, the channel of the other. The vibrations, which a sonorous body when it is struck, raises in the air, and from thence in the auditory nerve, excite in us the idea of sound. In the same manner, the vibrations which a luminous body raises in the ethereal matter, and from thence in the optic nerve, excite in us the idea of light.

If the air be entirely excluded from any place, which may be done by the help of a certain machine, a sonorous body put into that place would not be heard to sound. In the same manner if it were possible to exclude the ethe-

real matter from any place, a luminous body put into that place would not appear resplendent.

The greater or less force of the vibrations on the air, or the auditory nerve, produces a great or less intenseness of sound. In the same manner the greater or less force of the vibrations on the ethereal matter, or the optic nerve, produces a greater or less intenseness of light.

The different quickness of the vibrations on the air, or the auditory nerve, produces different sounds, as bass, treble, and their different degrees; so after the same manner, the different quickness of the vibrations raised in the ethereal matter or the optic nerve produce different colours, as red, yellow, and the like, which may be considered as the tones of light.

I do not believe, said the Marchioness, that even our preachers ever carried a similitude farther than this. It may be carried still farther, answered I. As various and different vibrations cross and intersect without destroying, or rather, without giving each other the least interruption, which we every day see in consorts of music, where the vibrations of the strings of a violin do not interrupt those of any other instrument, so the different vibrations, which flow to our eye from different colours, do not interrupt each other, notwithstanding they cross and intersect. The fluidity of these vortices gives them a power of transmitting the vibrations of different colours to various parts, which the solidity of the globules would not suffer them to do; in the same manner as the fluidity of the air does the different sounds in a concert of music. The explication of this seems so very difficult to Malebranche, that he affirmed a system, capable of effecting it, must be conformable to truth.

Sound and light, replied the Marchioness, appear to be as faithfully copied from each other, as nature was by the paintings of Apelles, which were so very accurately done, that an astrologer could predict the future fortune of the persons whom they represented.

I have not yet finished the comparison, answered I. An object, placed between two looking glasses over-against each other, will be greatly multiplied. One candle is changed into a thousand, and brings to mind the celebrated annual feast of the illumination of candles among the Egyptians, from which, some imagine the Chinese to have borrowed their feast of lanthorns. And does not the famous echo of the castle of la Simonetta, not far from Milan, produce the very same effect upon sound? The report of a pistol in this place is repeated more than forty times, and a single instrument of music forms a fulness of sound superior to that of the most numerous concert. Two great wings of a building opposite to each other with windows, which are all false except one, and formed of a matter very proper to throw back the vibrations, reflect and multiply the sound just as the two glasses do the candle.

The great lord Bacon, the harbinger of true philosophy, has among innumerable other curious things, proposed the examination of this affinity, betwixt light and sound, to the consideration of naturalists. Perhaps he could not have wished to find a more close union betwixt them, than what the system of Malebranche discovers. But he advised too, that philosophers should carefully examine in what points they might disagree; and the greatest difference betwixt them is, as I first told you, that the channel of sound is the air, and that of light the ethereal matter. Hence it follows, that sound must be propagated from a

sonorous body in time; for the spaces and interstices between the particles of air make it absolutely necessary, that there should be some little time before the motion can be communicated from one particle to another. Light on the contrary must be propagated in an instant, or an exceeding little space of time, because there are no spaces betwixt the vortices or ethereal matter, since the whole universe is every where filled with them. Light and sound have the same resemblance to each other as the Nereids engraved by Vulcan upon the silver gates of the sun's palace, in Ovid's Metamorphoses. Their features are not exactly the same, but so extremely like, ~~that~~ ^{but} it is very easy to perceive they are sisters.

Let us then become reformed Cartesians, said the Marchioness, by accepting a reformation which not only explains all that the globules did, but something more, and of much greater importance, which they were not able to explain. Let us adopt Malebranche's system of light and sound, these two new brothers in natural philosophy. I do not absolutely despair, answered I, but the harpsicord of colours, and the music of the eyes, which gives a still greater confirmation to this new alliance, may in time meet with a favourable reception from you.

What do you mean, replied the Marchioness, by this new invented music and harpsicord? Have you a mind to ridicule the philosophical similitude you have been entertaining me with? I should be sorry, answered I to have any temptation to ridicule what you have adopted instead of your globules. This harpsicord is indeed a new invention, but is not therefor the less true or real. Upon moving the keys of this instrument, instead of hearing sounds, you will see colours and mezzotintos appear, which will

produce the same harmony as sounds do. The sonatas of *Rameaux* or *Corelli* will give the same pleasure to the eyes when seen upon this philosophical harpsicord, as they do to the ear when they are played upon the common sort. The concords of a piece of purple and scarlet will raise the passions of love, pity, courage, or anger in our souls: this surprizing instrument is now making beyond the mountains, and you may for the future expect your silks and ribbons in music. The transient pleasures of the ear will be fixed in the eye; you may continually enjoy the fine airs of *Farinelli* wove in a piece of tapestry.

The inventor, answered she, probably took the first idea of this, from the dress of a harlequin. However, we are greatly obliged to him, for we shall have no occasion to embarrass ourselves for the future in adjusting the colours of our clothes. We need only consult the thirds and octaves of this harpsicord, and we shall be sure never to make any discord in the shading. The painters, answered I, may find relief in their indispositions from this new invented music of colours, as singers and musicians are said to do from that of sounds.

Why will you restrain the effects of so singular a thing, said she, to the painters only? It will help physicians to increase their prescriptions and prolong their consultations. Physicians, answered I, must act with regard to their patients, as musicians do with weak voices; and as those are careful not to discourage their scholars with difficult notes, so these in certain distempers, as the bite of a tarantula, which can be cured only by pleasure, must take care not to prescribe any colours for which the patient has an aversion. But we must leave the physicians to divert their patients in this new method as they judge proper. This

new instrument will help to give us a proof of the justness of that fine comparison made by an elegant poet between the gradual languishing and dying sounds in the voice of our tuneful Orpheus, and the insensible fading and vanishing of the colours in the rainbow. Who knows, replied the Marchioness, but we may some time or other form a dinner by the assistance of a harpsicord, and find harmony in a fricassée?

After his discourse, as we are taking the air in the garden, the Marchioness suddenly cried out,—What shall we do! I see a gentleman in the neighbourhood coming towards us, who in every visit he makes does me the favour to repeat sonnets by the hundred, and yet always finds time for some ode. How shall we disengage ourselves from his troublesome company? Will there be no vortex so merciful as to snatch him away with itself, and remove him from our system? For want of a vortex, answered I, we will serve him as I once did a mathematician, who happened to be very talkative, a fault which those sort of people are seldom guilty of. When you are walking with a friend, and discoursing about the country of Kouli Kan, or some such trifle, he will entertain you with the most abstruse points in geometry. He assaulted me one day as I was walking with some company in a garden, and we presently found by his air, that he was preparing to torment us with his demonstrations and corollaries. I and the others who were with me began to talk of poetry, and repeat verses, a language to which he was an utter stranger, without suffering him once to open his mouth. By this means we compassed one of the most difficult enterprises, that of tiring the most tiresome person in the world. Now we need only continue our discourse upon philosophy,

and I will engage your sonneteer will suffer the same punishment as my mathematician. Thus we resolved to proceed.

After the first compliments were over, the poet, who knew nothing of our scheme, took occasion to inform us, that the muses had for a long time used him ill, and that he was resolved to renounce them for ever. After we had civilly contradicted him, he answered, that he was ready to prove his assertion by a few sonnets which he had lately made, and which would shew us, how very little he was in their favour. If they are really so perverse, said the Marchioness, taking him at his word, you must entirely abandon, and never think of them again. We have just been discoursing on philosophy and optics; it will be taking an effectual revenge if you enter into our conversation, which is so very different from poetry. He excused himself by saying that he had not a capacity for such sublime subjects, and though it was necessary sometimes to shew a little resentment, he must take care not to affront the muses too much. He observed that a little poetry would alleviate the severity of our philosophical discourses, and alleged the example and authority of Plato, who did not think it beneath him to write love-verses to Agatis, and engrave the three Graces on the citadel at Athens, with the same hand with which he had wrote the institutions of his Republic, and the *Timeus*, and in this manner divided his time between philosophy and the arts of Apollo. But all these arguments could not prevail on us to let him repeat his sonnets, which was the chief design both of his visits, and all that erudition which he had lavished upon us.

The Marchioness asked me several questions, which our poet did not think at all a-propos. Among the rest, she

was very anxious to know whether she might rely upon Malebranche's system of light and colours; for the destruction of the globules made her fear every thing, and her suspicions were terribly increased by this harpsicord. I answered, that such was the condition of all human things, that nothing must hope for a long duration here below, a truth which our gentleman could evince by many fine verses of the best poets, and perhaps by some of his own. I added, that I was extremely pleased to find the example of the globules had warned her not to place too much confidence in the reformation of father Malebranche. But that the most fatal blow to this opinion was, the being obliged to forsake it upon the account of that very analogy and correspondence betwixt light and sound, which at first seemed to give it so much lustre.

This analogy, continued I, fails in one of the parts, and in that part where it was most wanted. And this circumstance is sufficient to overthrow Malebranche's reformed system. All those fine resemblances, which you observed with so much admiration, cannot save it from destruction.

If an undulating motion happens to meet with any obstacle in its way, this does not stop its progress, for it bends on all sides, and continues to propagate itself in spite of the obstacle that opposes it.

A very familiar example will make you understand what I mean. If we were at the bottom of this hill, and some person on the opposite side of it should sound a French-horn to proclaim the destruction of some innocent tenant of the woods, whose only fault is the pleasure we find in destroying him by the help of our reason and contrivance, we should hear this sound notwithstanding the whole hill

is placed betwixt the horn and our ear. The reason of this is, because the undulations raised in the air by the French horn do not stop their progress when they meet with the hill, but giving way on every side and bending all round it, communicate the like vibrations to the opposite air. After the same manner, if you throw a little stone into this basin, the undulations formed in the water will not stop when they meet with the pipe, but giving way all round it, will communicate themselves indifferently to all the water, and thus the effects of it will be discovered in the whole basin.

You see then that if light were nothing but an undulation of the ethereal matter communicated to it by the vibrations of the lucid body, no interposed body could ever deprive us of the light of the sun or any other luminous object, or in other words, we should never have any shadow, which, especially in this season, would be a terrible inconvenience brought upon us by Malebranche's system. The pressure of Des Cartes' globules could give us no assistance in this case.

Thus Sir Isaac Newton, the avowed enemy of imaginary systems, and to whom you are indebted for the true idea of philosophy, has at one blow lopped off the two principal heads of the reviving Cartesian Hydra.

Though the Marchioness perceived the force of this argument she did not seem greatly displeased with it. As she had renounced the globules, she easily gave up the vortices. But our sonneteer was not quite so well satisfied. As he could find no opportunity of discharging his poetic fury, he was obliged to go some where else, to find an audience to a satire, which it is very probable he had begun to compose against philosophy.

D I A L O G U E IV.

*Encomium on Experimental Philosophy, and an Exposition
of the NEWTONIAN System of Optics.*

THE next day when we had disengaged ourselves from poetry, which had at first given birth to our discourses on light and colour, and afterwards endeavoured to disturb and interrupt it, I began after the following manner. It is now time, madam, to lead you into the most retired sanctuary of philosophy, from whence the prophane and those who are filled with vortices, globules, atoms, subtile matter, and like imaginations, are entirely excluded. This philosophy, which I am now conducting you to, is less pompous than that we have already discoursed on, but in return performs all its promises; a philosophy, which is contented with giving a history of physics, and leaves to others the province of making them the subject of a romance. You have had an instance of the one in its method of explaining the nature of vision, and the system of vortices has given you an example of the latter more pompous and splendid philosophy, which boldly goes to the first causes of things, and laying down certain arbitrary principles, upon these builds the world, and explains all the phænomena of it according to its own fancy.

As the eye is now discovered to have an entire resemblance to the artificial *camera obscura*, all philosophers will hereafter explain the nature of vision after the same

manner. But there will not be that conformity in their opinions concerning the solidity of bodies, gravity, light, and colours, since the cause of these qualities can be known only by conjecture. And how very hazardous a thing this is, you have already seen in the Cartesian system of globules, to say nothing of Mallebranche's reformation, which, notwithstanding all the applauses at first given it, is now exploded, and shares the same fate as the globules. And this you may believe has been the case with all the general systems that have hitherto appeared, concerning the causes of things. They resemble vast empires, which totter and fall by their own weight and greatness. I find then, said the marchioness, that the *wherefore*, which so greatly excites our curiosity, will be for ever hid from us, and the pleasure of conjecturing, which is generally so adapted to the taste of men, will have no charms for philosophers. This really is a circumstance, which will make the condition of these gentlemen not greatly to be envied by the vulgar.

Conjecture, answered I, according to the assertion of one of the most ingenious authors in the world, is not to be allowed in any thing but geometry. In this science, if the certainty of principles does not directly guide us to what we seek, it never leads us however to any thing contrary, and always rewards our searches with somewhat equivalent. But what uncertainty and inconstancy is there in natural philosophy? Some affirm that there is a vacuum, or space void of all body, and others will have every thing to be body. This diversity of opinions, with regard to principles, must unavoidably produce very great and innumerable disputes as they advance further, which extend so far as the fixing the essence or nature of body, a thing

which one would imagine should of all others be the most certain in physics, since body and the properties which depend on its essence, are the perpetual subject of philosophical inquiries. I cannot help comparing these philosophers to those critical writers who correct some corrupted and defective passage of an ancient author. One of these gentlemen gives one reading, a second another, each supported with the finest and most elaborate arguments, and the encomiums of the journalists of the learned. Some old manuscript of the author at length appears drawn out from the dust and obscurity of a library, and then all the fine readings of these profound critics, and the time they spent in inventing them, are sent into the regions of Ariosto's moon, and are there treasured up among other lost things. Observations and experiment are the authentic and original manuscripts of nature; and these, by overthrowing so many fine systems, instruct us every day to be more cautious in puzzling ourselves to form hypotheses. I look upon this advice as a very great benefit to mankind, since it exempts them from no small trouble and fatigue. But the misfortune is, that men persist in a refusal of this friendly admonition, and are obstinately bent to spend their time to no purpose.

This is indeed a practice that redounds greatly to the honour of these observations of yours, said the marchioness. A system need only be ingenious, simple and elegant, to give them a right to declare open war against it. They may be termed the Erostratuses of natural philosophy, who found their glory in the destruction of all that is great and splendid. I must confess that I cannot be pleased with so malicious a character. To what a height would your dis-

pleasure rise, answered I, if I had told you all that these observations are capable of effecting. There is perhaps no system better grounded than this, that animals have wings given them in order to fly, and legs to walk. And yet observation has discovered to us certain insects who have large wings without making use of them to fly with; and in the same manner, there is one animal, which, notwithstanding it has legs disposed like that of others, formed in the same manner and of the like proportions, yet almost always walks upon its back with its legs upwards, just as if the first were not sensible they had wings, nor the last, legs. It is true, however, that if observations had done no greater service to the world than to destroy, we should not be much indebted to them. But by overthrowing perplexed and useless, and sometimes very troublesome systems, how many good and useful discoveries have these observations furnished us with, in the room of those hypotheses they have overthrown?

Some melancholy philosophers have imagined the rays of the moon were cold and humid, and therefor greatly to be feared, since there must be expected very dangerous effects from their influence. And in fact you see many persons, even now, who, believing the effects of this planet from the tradition of their fore-fathers, retire as soon as ever the moon begins to rise, and, as they express it, gets strength; and vast numbers of people are persuaded that they have the head-ach, if by walking in the evening they have unhappily been obliged to receive the infection of its light.

The experiments, which have been made upon this, give us full liberty to walk at what hour we please, without apprehending any danger from that quarter. The rays of this planet, collected in the focus of a burning glass or a lens, do

not cause any sensible effect in the bodies upon which they fall, notwithstanding they are sometimes two thousand times denser when thus collected, than they ordinarily are. A thermometer, which is an instrument containing a liquor that contracts with the least cold, and dilates with the least heat, does not suffer an alteration in the focus of these glasses when they are exposed to the rays of the moon; whereas, if they are exposed to those of the sun, the vehemency of their heat surpasses that of the hottest furnaces; so that the *amiantus*, which defended the precious ashes of antiquity from the devouring flames of the funeral pile, cannot defend itself from the violent heat of those glasses. The rays of the moon do not appear to have any other quality, than that of supplying the absence of the sun, and inspiring a soft and pleasing melancholy in the hearts of lovers.

These sorts of observations, said the Marchioness, I have no objection to, which let the fine systems alone, and deliver mankind from ill-grounded fears. To this spirit of observation, answered I, we are indebted for our deliverance from other much more impotent fears; comets, pillars of fire, showers of blood, and *ignes fatui*, anciently marks of divine wrath, do not at present disturb so much as one half hour's sleep, except it be in those persons, who will always be the vulgar, and always of a temper fitted to receive these impressions of terror from others.

But how much are we indebted to the study of experiments! Astronomy, natural history, and anatomy, seem by the assistance of this to be rather new sciences born among the moderns, than transmitted from the antients to us. To this, anatomy owes the circulation of the blood, and all the animal œconomy, whose very simplicity was the

cause of its being so little known among the antients. To this, chemistry is obliged for its phosphorus: astronomy, for its exact predictions: hydrostatics, for an easy method of living, and carrying fresh air for respiration, in an element denied to men: for acoustics, and their speaking trumpet; their projects, for rendering the perfection of hearing equal to that of sight, and innumerable musical instruments, the offspring of harmony. To this optics owe their telescopes, microscopes, magic lanterns, and an infinite number of other wonders, that perfect or flatter the sense of seeing.

Superstition, credulity, and a greater love for the marvellous than truth, negligence, and a want of proper means for observation, have for a long time been insuperable obstacles to knowledge. How great a treasure of wonders has natural history, after having rejected the absurdities of the antients, demonstrated to us! New modes of production, breathing, seeing and living, new conformation of parts, new societies, new modes of being, unheard and unknown to past ages.

The reason of mankind has been polished in proportion as that of brutes has been more considered; and the arts themselves have been brought to perfection by observation upon certain animals, commonly regarded either with horror, or as the refuse of nature. Spiders have furnished our manufactures with new species of silks; and the eggs of a fish, though yet unknown, may, with a little apparatus, give us a fine purple colour not inferior to that so much celebrated by the antients. Shall I inform you of the experiments made concerning the weight of air, and the power it has of dilating itself when compressed? experiments once termed the wonders of Magdebourg. Shall

I give you an account of the equilibrium of fluids, the vegetation and culture of plants, which have afforded so great an advantage and ornament to society? By these experiments your garden is embellished with the playing and agreeable murmur of artificial fountains; and these supply the northern tables in great plenty with those delicious fruits that nature had confined to a warmer hemisphere. The orange, by these transported from China to the Portuguese soil, sweetly allays the burning heat of the summer; and these experiments have extracted from the vines of the Rhine transplanted upon the burning rocks of Canary, that agreeable juice so pleasing to the taste of ladies. Still better and better, said the Marchioness. Is not this the cluster of the promised land by which you hope to allure me? and as we are in the country, would intice me, by the hopes and advantages which accrue from observation, to agriculture and œconomy? Without dispute you have those antient consuls in your head, who from the triumph returned to the culture of their farms.

If I had a design of inticing you, answered I, Madam, I should rather entertain you with talking of the polite arts of which you are so fond, and which owe both their original and progress to observation and imitation. Gratitude requires you to think yourself obliged to these for the pleasure you receive from the fine lineaments and elegant air of countenance in the Medusa of Strozzi, the just gradation of the anger of Achilles, the variety and strength of passions in Cassandra, that master-piece of the Timotheus of our age, the majestic solidity of the Portico of the Rotunda, the elegant strokes of Guido, and the magic colouring of Rubens. What riches has this industrious philosophy brought into the treasuries of painting, by the

observation of so many new animals and plants? what an additional beauty has it given, by the imitation of the eastern varnish, to certain works designed for the use of those people to whom superfluity is necessary? what a fruitful source of similes and descriptions has it by its new discoveries opened to poetry? The sun, stars, shepherds, the Hyrcanian tiger, and the like common-place comparisons, are delivered from the weight which they alone have long borne in poems, and we from the fatigue of hearing them so often repeated. How great a progress has the elegance of dress, which so greatly heightens the beauties of nature; and in short, the most polite of all the arts, made in our age, by the assistance of a curious observation made upon pleasing objects! beauty itself, the most valuable treasure with which nature can enrich and adorn youth, would often be a vain and useless gift, if observation had not consulted its safety, by bringing in the strange, yet salutary art of furnishing ourselves with a particular distemper whenever we please. How many fair Circassians, who, formed for the pleasure of the universe, are confined to a seraglio, and subjected to the caprices of one single tyrant; and how many beauties in England, the mistresses of free-born hearts, owe their empires and their arms to an early inoculation of the small pox?

But not to insist on what you may possibly think I might acquire too great an advantage from, not to say any thing further of natural philosophy, which seems a province the most adapted to the discoveries of observations, is not policy indebted to *these* for that wise and real government, which renders the southern sun less pleasing than the cloudy regions of the north, where the liberty of the people is made compatible with the authority of the sovereign?

Metaphysics, that labyrinth of reason, are obliged to these for a certain system of the origin and progress of our ideas, and we for the knowledge of our selves. The chaos of chronology and history has from these observations received its light and order. Sir Isaac Newton, that divine philosopher, who may be regarded as the founder of human knowledge, has from observations drawn chiefly from the ordinary course of nature, ranged historical facts in a certain series, by joining epochas, which the ignorance or pride of mankind had set at a great distance from each other, in the same manner as a judicious observation had united the boundaries of the earth in geography.

Conducted by this infallible guide, he, according to the expression of one of his countrymen,

Display'd the lucid robe of day,

and thence extracted the true properties of light and colours, which had till that time lain concealed and involved, without forming, like Des Cartes and his followers, any imaginary system to explain the nature of them.

This is a world entirely new, enriched with the most shining truths, and discovered by Newton alone; for there are not the least traces of any philosopher who ever appeared there before him. His treatise of optics, the production of thirty years study and search, is an excellent model of true philosophy. One single experiment of his has advanced our discoveries more than all the ingenious and magnificent systems put together, that had ever gone before him.

An antique column of the most worthless stone has more beauties in the eyes of a connoisseur, and will conduce more

to the perfection of architecture, than all the galleries of emerald and adamant, invented by the poets to adorn their enchanted palaces.

But your connoisseur, said the Marchioness, cannot admire or taste the beauties of a column, however antique and well-proportioned it may be, unless he first knows what a column is. And how is it possible that we should understand the properties of light and colours, as you tell me Newton does, without first fixing what the colours themselves are, and explaining the nature of them? Des Cartes, whose system you moderns explode, tells me, that if a ray of light meets with the solid parts of a body, it is repelled and reflected, and I understand this very well, because he had before told me that a ray of light is nothing but a string of little globules. But how can I ever understand the new discoveries concerning the qualities of light, unless I am first informed what light itself is?

Is there any thing, answered I, more inexplicable than the nature and causes of muscular motion? All the dissertations of philosophers upon it have been in vain. And indeed the more these dispute upon the causes of things, the more inexplicable do they generally make them. And yet an excellent painter, a Michael Angelo, by laying down certain rules drawn from repeated observations, would have informed you, that when the body makes such a particular motion or effort, certain muscles must be elevated, and others lowered and depressed. So that there is no posture so strange but he could have foretold the various and almost infinite motions they could produce. The famous piece of the last judgment, in the Vatican, is an evident proof of his knowledge in this point.

The loadstone is a secret of the same kind. Its nature

and the cause of its surprising effects are, and perhaps always will be, as entirely lost to philosophers as the *Punic* language is to Critics.

Our ignorance of its cause, however, does not hinder us from making very many discoveries of its qualities. We know, for instance, that if it be armed with steel it can attract a much greater quantity of iron than it can unarmed. We have discovered, that on one side it attracts another loadstone, and repels it on the other, and constantly directs itself to the poles of the world. To this, natural philosophy owes the discovery of a great number of truths, to this navigation its compass, and commerce and mankind very many advantages.

If it is ever possible to arrive at a knowledge of the nature of things, this is the only method, by observing and investigating, with the greatest attention, their most secret and hidden properties, their primitive and elementary qualities, on which all the rest depend.

I observed to you the other day, answered I, that every ray of light, however slender, is nothing but a collection of innumerable other rays, which are not all of the same colour, notwithstanding the whole ray appears white : but some of these rays are red, orange, others yellow, green, blue, indigo, or violet, besides innumerable degrees of intermediate colours between each of these seven principal ones. These rays of different colours, which are called *primary* or *homogeneous*!, blended together form a heterogeneous compound ray of a white or golden colour, such as a ray of the sun appears, just in the same manner, as different colours mixed together upon a painter's pallet, compose a new one, which has something of all the others in general, but is different from each of them in particular.

These are the reasons why that poet, whom you discovered rather from his esteem for you, than by his stile, in speaking of light, uses the expression, *golden and sevenfold*, an epithet antiently appropriated to the Nile, and the shields of heroes. This *sevenfold* light is the inexhaustible treasury of those innumerable colours, which form the gay picture of the universe, and its rays are not tinged with the purple or saphire, either when they are refracted through a prism, or reflected from a surface, but derive their colour from the sun himself with that heat and lustre, which they receive from him, though not discovered by vulgar eyes.

In short, every ray may be considered as a fibre composed of innumerable other fibres or filaments, each of which has a peculiar, a proper and unchangeable colour, which it would infallibly discover to our eyes, if it could be seen, separated from the other colours, which concur with it in forming the white or yellowish colour of light. But how indefatigable must be the industry of that philosopher, who could divide and resolve the whole ray into its primary and elementary rays, so that every one of them should exhibit its own colour? It is certain this division could never happen, if these primary and homogeneous rays were not of such a nature that some are refracted more than others, in passing all with the same inclination out of one medium into another, from air into glass, for example, and by this means are disunited and separated from each other.

This proposition, that *rays which differ in colour differ also in degrees of refrangibility*, is the fundamental discovery, upon which the Newtonian system of optics is built. Agreeably to this it is demonstrated that the violet rays are

the most refrangible of all. Next follow the indigo, then the blue, green, yellow, orange, and lastly the red, which are the least broken of any by refraction. Do I explain myself clearly enough, Madam, for you to conceive my meaning?

Extremely well, answered she: I understand very easily, that nature, by making rays which are different in colour different likewise in refrangibility, has furnished philosophers with a means of separating them, which otherwise would be impossible. The properties of this light, which you have been describing, are indeed very surprizing. A philosopher must have a very great and enterprizing genius that could make such discoveries; and his credit ought to be supported by very weighty arguments drawn from frequent observations, which I must confess I am extremely impatient to be acquainted with. I who was at first a Cartesian, afterwards a disciple of Malebranche, now find myself without any system at all. This is a vacuum that does not greatly please me, therefor I am in haste for it to be replenished with other observations.

These will very soon amply repair the losses you have sustained by them, answered I. It would be well if every thing else in the world, that does us an injury, would make as good a compensation for it.

Imagine yourself to be in a place of Milton's visible darkness, or rather still darker a place, if you will be absolutely deprived of all light; and this shall be our theatre of reasoning and observations.

Let a ray of the sun enter in at a hole made in the window shutter, and let a glass prism be placed horizontally at this hole, to refract the ray in such a manner as to throw it upon a wall opposite to the window, so that as it is going out of the prism, it is almost horizontal and parallel

to the pavement of the chamber; whereas if it had not been refracted, but direct, it would fall upon the pavement itself, and there form a white image of the sun of a figure almost round. That spectrum, or image of the sun, which the refracted ray forms upon the wall, is very different from that which the direct ray formed upon the pavement; for as the image of the direct ray was almost round and entirely white, that of the refracted ray is of a figure nearly resembling a fish at cards, and varied with an infinite number of colours, among which the seven primary ones are distinguished and placed in a shining order, one after another.

*The jolly peacock spreads not half so fair
The eyed feathers of his pompous train;
Nor golden IRIS so bends in the air,
Her twenty-colour'd bow through clouds of rain.*

FAIRFAX.

I am very glad to find that Tasso, said the Marchioness, who had before a little transgressed against the laws of refraction for the sake of his Armida, has amended his fault, and is at present reconciled to optics.

These colours, answered I, with which the image is painted, are disposed in such a manner, that the red is in its lower extremity; above this is placed the orange, afterwards the yellow, then the green, the blue, indigo, and lastly the violet, which is placed in the upper part of the image. Innumerable degrees of intermediate colours insensibly connect and unite the same primary ones. Neither Correggio, Titian, nor his rival Rosalba, did ever unite and shade their mezzo tinto's with so much exactness to form the oval of a face.

In order to explain this great change, we must suppose

one of these two cases; either that light is composed of rays differently coloured and differently refrangible, so that the prism does nothing but separate them from each other, when they are transmitted through it; and by this means the different colours are formed, and the image which would otherwise be round, is of an oblong figure: this is one manner of explaining this phænomenon. The other is, that the light in passing through a prism, acquires colours which it had not before, and moreover, that every ray is shattered, dilated, and split into many other diverging rays painted of a different colour; and this is the reason why the image is coloured, and of an oblong figure.

This last is the supposition of Grimaldo, a philosopher, who preceded Sir Isaac Newton; and this system is called the *dispersion* of light. You see it is necessary, unless we admit the different refrangibility, to suppose this dispersion, in order to explain why the coloured image of the sun should have a length much greater than its breadth, after being refracted by the prism.

This experiment, said the Marchioness, which has cost me so much attention to understand, and this oblongitude of the solar image, are not sufficient to prove the different refrangibility, because all this phænomenon may be as well explained by Grimaldo's dispersion of the light, which is a system very different from Sir Isaac Newton's. I want to see some experiment which cannot possibly be explained by any other system than the Newtonian, and that I believe would satisfy me. This, answered I, is the very thing necessary to prove not only the different refrangibility, but every other principle in philosophy; and this, Sir Isaac Newton has done, without knowing, perhaps, that it would one day give pleasure to

a fine lady, whatever a certain author may say to the contrary, who accuses him with having drawn more consequences from his observations than he ought to have done, one of the greatest faults that a mathematician can be charged with. This author reproaches Sir Isaac, with having inferred the different refrangibility of the solar rays from the preceeding observations; whereas Sir Isaac declares in exprefs terms, that the observation is not sufficient for that purpose, because this strange appearance of the image may proceed from the shattering of the rays, as Grimaldo supposes; or from an inequality of refractions, not constant, but only casual, and therefor can have nothing deduced from it. The more scrupulous this great philosopher appears in his reasons, the more licentious does his adversary seem in his accusation. In order to remove the dispersion of Grimaldo, and the fortuitous inequality of the refractions, he invented the following experiment, which is, as it were, the arbitrator and judge of the controversy.

He received the coloured image formed by the prism, and cast upon the wall, upon the face of another prism placed upright in such a manner, that the red of the image should fall upon the lower, and the violet in the superior part of this face, and the other intermediate colours should fall respectively in the intermediate spaces betwixt the red and the violet.

If the first prism, which was placed horizontally, refracted the rays upwards, this second, placed upright, must refract them sideways, either on the right or the left; so that if they were at first thrown almost directly upon the wall opposite to the window, they must now strike it oblique, and with some inclination. The refra-

tion then which the colours are to suffer in passing sideways through this second upright prism, is the thing which must determine the question, either in favour of Sir Isaac Newton's supposition of the different refrangibility, or for Grimaldo's notion of the shattering of the rays, or lastly, must give the preference to a fortuitous and casual inequality of the refractions, which cannot agree with any system at all. For, if the solar image, formed by the first prism which refracted the rays upwards, received its colour and oblong figure from a dispersion or dilatation of every incident rays, a second transverse and sideways refraction, caused by the second prism, must after the same manner shatter and dilate the rays of this image sideways, and render it of the same oblongitude in breadth as it had before been in length; so that a new image would be painted upon the wall of the chamber, which is behind the second prism; and this image would be coloured differently from what it was before, and be changed from an oblong figure, to one almost square.

Lastly, if the colours and oblong figure of the image formed by the first prism, were occasioned by a fortuitous and accidental inequality of refractions, who can tell what variations chance might have produced in the combination of the second prism, and in the new refraction which that prism gave to the light?

Whatever effects chance might produce in this case, it is certain it could never agree with what the Newtonian system aims at. According to this system, if the colouring and oblong figure of the image formed by the first prism, were occasioned by the separation of rays differently coloured and differently refrangible, a second refraction, made sideways, can only incline this image, and must

leave it just the same as it was before with regard to its colours and oblong figure.

How will it *incline* the image, said the Marchioness? I do not understand the reason of this. You will soon understand it, answered I, when you reflect, that if the second prism was removed, the rays would all strike the wall almost in a direct line. Now if the second prism refracts the violet rays, that is, turns them sideways and transversely out of their path, more than it does the red, those must strike the wall more oblique than these, or in other words, the violet must fall at a greater distance from the prism than the red. The intermediate colours too, between the red and the violet, will fall upon intermediate places of the wall: thus the image will appear inclined, and as it were leaning with its violet extremity farther from the prism than the red is. These effects must happen according to Sir Isaac Newton's system; and these in reality do happen, as I myself have often had the pleasure of seeing.

If after the second prism, there be placed a third and fourth, in order that the image may be successively refracted sideways through them all: those rays which were refracted more than the rest in the first prism, will be more refracted too in the following prisms. But the image will not be dilated sideways, nor coloured differently from what it was at first.

Nature, said the Marchioness, has pronounced the grand judgment, and of three systems that contented for it, the Newtonian has carried the golden apple. I must confess this decision does not displease me; for to say nothing of the accidental inequality of refractions, which does not deserve the prize, Grimaldo's supposition of the shattering

and dilatation of every particular ray, had something too perplexed and imbarassing in it. If you think the judgment which nature has pronounced in favour of our philosopher, answered I, to be so just, that of his adversary, whom I lately mentioned, will appear extremely capricious, who asserts, that Sir Isaac Newton has, by agreeable experiments, confirmed the observations of Grimaldo. I am not so greatly surprized at this adversary, replied the Marchioness, who does not appear to have any great knowledge of the matter, as at Grimaldo himself, who neglected to prove the truth of his dispersion of the rays, by so easy and simple an experiment as this, which requires nothing more than a second prism after the first. One would imagine, that it should have been very obvious to a person bent upon making a system. Say rather, answered I, to a person long exercised in the arts of observation; for a love of building systems, and making experiments, are two things that seldom go together. But it generally happens that the most simple things are the most difficult, and consequently the longest before they are found out. The circulation of the blood, for example, appears to be a very easy discovery, and one would imagine should have been very antiently made. When an orifice is opened in the arm, the arteries swell from the heart towards the extremities of the body, and the veins, on the contrary, from the extremities of the body towards the heart. This evidently shews, that certain vessels, that is, the arteries, are designed to convey the blood from the heart to the extreme parts, and other vessels, namely the veins, to carry it from the extremities to the heart. Besides, the death of Seneca might have furnished the antients with a physical experiment, as well as a moral precept. It was im-

possible that all the blood should be emitted through the opening of the veins, unless those of the superior parts had a communication with those of the inferior; or in other words, unless it circulated through the whole body. It appears then that it was much easier for the antients to discover the circulation of the blood, who had so many experiments ready prepared to their hands, than for Grimaldo to find the falshood of his dispersion, because his experiments must have been the effect of his own labour and invention.

It is true, some bigots for antiquity pretend to find this discovery in Hippocrates, so that according to them, all the inventions of the moderns, and all our distempers, were known to the antients. But this notion is the same as if a Vellutellus, or some other zealous admirer of Petrarch, should discover the Newtonian system of optics in these verses,

*While the great author of his frame expires,
The conscious sun withdraws his active fires;
Pale sickly shades ov'rspread his languid ray,
And ev'ry beauteous colour fades away.*

The most simple things are generally discovered the latest, and with the greatest difficulty. This aphorism, said the Marchioness, is too well verified even in the toilet, where an elegant, but simple disposition of our hair, or our patches, often costs great trouble, and the utmost anxiety of mind.

According to this principle, answered I, Sir Isaac Newton's experiments must have cost him an infinite deal of labour. For if the preceding experiment, to prove the

different refrangibility of the rays, is at once simple, agreeable, and conclusive, all the others which he invented for the same purpose, are no less perfect, and yet appear so very obvious, that every one would imagine he himself might have as easily found out.

How, said the Marchioness, is not this experiment sufficient to prove the different refrangibility without seeking for any more? Have I acted wrong, in suffering myself to be too easily convinced? No, Madam, answered I, a lady cannot err in this point. But Sir Isaac Newton himself does not desire you should assent to his system so soon. This experiment, without dispute, is sufficient to demonstrate the different refrangibility, but not to satisfy a philosopher resolved to try nature a thousand ways, and put her to a thousand proofs, in order to establish his belief on a sure foundation. You seem, said the Marchioness, to represent nature as a coquet, and Sir Isaac Newton as a jealous lover, who never thinks he has proof enough of the fidelity of his mistress. This, however, answered I, was the only object of his love. I am very sorry, that I cannot shew you all the experiments which he invented for this purpose, in order to present you with the most finished and beautiful piece that philosophical jealousy ever composed. But the parts I shall shew you will assist you to form an idea of the whole, just as the obelisks and amphitheatres discover the grandeur of antient Rome. Let me intreat you, said the Marchioness, to make me a complete Newtonian. I plainly see that by my conversion I shall acquire the knowledge of truth without losing that pleasure which I found in being deceived.

In the dark chamber which we have prepared for our experiment, continued I, let a white thread be extended

horizontally against the window, but at some little distance from it. Let two rays of the sun enter at two holes made in the window-shutter, which, refracted by the two prisms, may paint two coloured images upon the opposite wall. When this is done, we must recommend ourselves to the genius which presides over optics, and then patiently wait till the half of this thread be illuminated by the red rays of one image, and half of it by the violet rays of the other. Let the wall opposite to the window be covered with a black cloth, that the colours which would otherways be reflected by the wall, may not disturb the experiment; for at present we want no other colours but those of the thread, which must be alone distinguished. This thread must be observed through a prism placed before the eyes in such a position, that all the objects seen through it appear higher than they really are. The thread too will appear to be transported higher by the refraction; but because the violet half should suffer a greater refraction than the red, it will be much more transposed than the red, so that the thread will appear divided into two parts, the one illuminated with violet, the other with red, and the red will appear lower than the violet.

This experiment, if we should exclude every other, is intirely agreeable in its parts to the Newtonian system. If the violet part of the thread be illuminated with indigo, the thread will appear less divided than at first, the indigo half approaching nearer to the red than the violet did, which must necessarily happen, because the difference of refrangibility between the indigo rays and the red, is less than that between the red and the violet.

If from indigo this half be illuminated with blue, the other half still remaining red, the thread will, for the same

reason as I before mentioned, appear less divided than at first, and still successively less if it be illuminated with the other colours in order, green, yellow, and orange, till at length becoming red like the other half, the thread will no longer appear broken nor divided in two as at first, but whole and continued, because now the colours of each half have no difference in their refrangibility.

A like experiment may be made with a paper, the one half coloured with red, and the other blue; placed afterwards upon a black cloth, and looked at through a prism it will appear broken and divided into two parts. A paper illuminated with four colours, which I have myself seen demonstrated, that is, red, yellow, green and blue, ranged one after another in the order I have named them, appeared through a prism divided into four pieces, like the steps of a ladder. The blue is sometimes the highest of all, and sometimes lowest, as the position of the prism requires. This experiment varied in as many ways as the fruitful imagination of Paul Veronese would vary the subject of a picture, always succeeded so well, as to have greatly confirmed this system, if its author suffered it to need any confirmation.

I must ingenuously confess, said the Marchioness, that though I have always regarded the mathematicians with a singular veneration, I do not yet understand what their demonstrations are. However familiar they may at present be rendered, I do not comprehend them enough to find the solution of a problem among the patch-boxes and perfumes on my toilette. I now begin to fear that my ignorance of the Deity I worshipped, greatly increased my veneration for it. Their evidence causes so great a noise in the world, that I was persuaded every thing else, however

well it might be proved, had only a small degree of probability when compared with these. At present, I cannot conceive it possible for any mathematical demonstration to be more certain than Sir Isaac Newton's different refrangibility, and yet this is a thing merely physical. But you are to consider, Madam, that the person, who has treated upon this physical subject, was the greatest mathematician that ever appeared in the world. We may affirm then, replied the Marchioness, that as every thing which Midas touched was transformed to gold, so every thing that Sir Isaac Newton handled became demonstration.

If ever physics could hope to vie in certainty with geometry, answered I, they might with some reason expect it, when treated by Sir Isaac Newton, though there is a very great difference in the nature of their proofs.

Physics can only consider a vast number of particulars, make observations upon them, and thence deduce general propositions; whereas geometry, by a more expeditious and certain way, abstracts particular cases, and founds its demonstrations upon nature; and the idea of the thing itself, whereon it treats.

All that a mathematician demonstrates to you concerning one triangle, will be true in all, be they of what species they will, because he considers nothing but what is necessarily included in the nature of a figure terminated by three right lines; and as this is found in all triangles that can possibly be either made or imagined, his proposition will hold true in all.

On the other hand, a naturalist will tell you, that all bodies here below gravitate, and if left to themselves descend; but he does not, like the mathematician, deduce this proposition from the nature of body, for that is un-

known to him, but from a daily observation that gold, silver, gems, water, air, and a thousand other bodies gravitate, and do it constantly by day and night, in summer and winter, fair and cloudy weather; from whence it may reasonably be inferred by induction, that every other body gravitates at all times, and in all places.

But however reasonable this method may seem, so great a demand for proofs implies a want of demonstration, just as a too great attention to dress, argues some defect of natural beauty in a face. Who can tell, but notwithstanding such a multiplicity of observations, some may question whether there be not a certain body with which we are yet unacquainted, that has no gravitation? or if there be not some country in the unknown tracts of the southern pole, where bodies have not that quality of gravitation which we discover them to be endowed with in all the known world? Or lastly, whether in past ages there may not have existed a certain body that did not gravitate? You will grant, however, said the Marchioness, that where the number of observations is so great as that from whence the gravitations of bodies, and the different refrangibility of the rays of light are deduced, that person must be inexcusable who doubts their evidence, unless it was prescribed him by a physician for his health.

If there are some, answered I, too excessive in their doubts, there are many others too bold in their assertions. All do not imitate the prudent and necessary reserve of our judicious philosopher: some are contented with one single particular case, from which they hastily deduce a general conclusion, like those who form a judgment of the temper and general character of a whole nation, from the parti-

cular humour of a single person, whom they have seen perhaps once or twice at a coffee-house.

Sir Isaac Newton's antagonist whom I lately mentioned, imagining he had overthrown the system, and principally the different refrangibility, in order to prove himself the opponent of this great author, even in the method of philosophising, has put together a general system, hinted at by others but not followed, formed upon particular cases, which, well examined, are nothing but consequences of that which he imagined himself to have overthrown. He supposes certain grounds, and a mixture of light and shade; and the different combinations of these are, according to his opinion, the cause of different colours.—Can a combination of light and shade, interrupted the Marchioness, ever produce red or yellow? A phenomenon must be very unfortunate, whose explication depends on this system. Perhaps, answered I, those phenomena which contradict general laws, those monsters of optics, if there are any such, are sent by nature to this system for their explication; and do not these fine colours of yours too deserve a little punishment for all the mischiefs they have caused? But see the unhappy condition of the poor prismatic colours, which certainly do not merit the correction that yours do; and from hence you may form an idea of the value of this system.

It affirms, that when a ray of the sun is refracted by a prism, these colours are produced by means of two sorts of images; the one formed by the dispersion of the solar rays, and the other, by that of the rays of heaven, which are contiguous to those of the sun. What, said the Marchioness, does this philosopher attempt to bring this *dispersion* again upon the stage? Had he never seen the expe-

riment of the second upright prism, which has for ever banished this supposition from the province of optics?

Authors, answered I, have their eyes formed differently from those of other men. The sun is light, and the sky comparatively dark. This was sufficient to furnish the philosopher we are speaking of, with abundance of relations betwixt light and shade, the veils, as he expresses it, formed by these two images, from whence he draws an explication of the difference of colours in a prism. I fancy, said the Marchioness, this explication will not be very simple; it appears to me sufficiently perplexed. Not to insist upon this and many other difficulties which this system is chargeable with, we will confine ourselves to the following objection, answered I.

If it be true that this diversity of colours depends on a mixture of the rays of these two images of the sun and sky, and from their shadding each other, it is certain that if there can be found a method to prevent the celestial rays from coming to the prism, and consequently from being refracted and mixt with those of the sun, the colours will vanish with all that fine theory which arises from the mixture of those two sorts of rays.

Now this may easily be effected, if before the ray of the sun, which enters at the window of the dark room, be refracted by the prism, the middle of the ray be transmitted through another hole made in a table, or a pastboard placed at some distance from the window: In this case, so far is the prism from receiving the celestial rays contiguous to those of the sun, that it receives no rays from the sun himself, but what flow from his disk, and is not at all affected by those that proceed from his edge. It is evident then, that if this system be true, the colours of the

images in this case could not appear, which is absolutely contrary to experience, a disgrace pretty familiar to this system.

You seem, said the Marchioness, to resemble Bacchus throwing down the giants, who attempted to dethrone the gods, in order to usurp their places. The spirit of ambition appears no less strong in this author, than in those presumptuous sons of earth.

You are to suppose, answered I, that an author is often as strongly desirous of giving his name to a new system, as a French lady can be of giving her's to a new fashion. How happy would they be, if, like that Chinese emperor, who burnt all the books of history preceding his reign, in order to make his name the first epocha of it, they could destroy all preceding systems to make their own the epocha of human knowledge!

Besides, Sir Isaac Newton's system came from a country too far beyond the Alps, to be favourably received among the Italians. It would be very surprizing, if a system, produced in England, had not been treated with aversion by some persons in a country so near the sun as ours. I do not see, replied the Marchioness, why a system should meet with the worse usage for being a native of England. For my part, as much an Italian as I am, I do not believe that I should be prejudiced against a well grounded one, even if it had been produced in Ireland, or Nova Zembla.

You are not to imagine yourself, answered I, to be ranked with the generality of mankind. A sea, a river, or a chain of mountains placed between some people and a certain truth, are insuperable objections to their reception of it. Perhaps as the Romans found a certain *Je ne sçais*

quoi, in the stile of Livy, which discovered the *Paduan*, so our Italians find a *Je ne sçais quoi*, in every truth that comes from beyond the Alps, which does not agree with their taste. These gentlemen, said the Marchioness, must have a very distinguishing judgment to discover such differences as these, or it rather argues, they have no taste for truth, who find any thing foreign in the proofs of a different refrangibility. In this I may venture to affirm myself a better Italian than they, since the least difference in this case may turn to our disadvantage.

You, Madam, said I, are a citizen of the world, and your senses formed for truth are proof against the objections of those who only appear to be zealous for it. You will find a new demonstration of the different refrangibilities drawn from the difference in the focus of a lens, through which the different colours are viewed. The image of the letters of a book, formed by a convex glass, illuminated by the red rays of a prism, appears distinct at a certain distance from the glass: the image of the same letters, when illuminated by the blue rays, is not distinct, but at a less distance. In the like manner, the four colours, red, yellow, green, and blue, of the paper we before mentioned, are not equally distinct when placed at an equal distance from the lens. The blue is nearest, next follows the green, afterwards the yellow, and last of all the red, whose rays being less refrangible than the rest, must be collected and united at a greater distance from the lens.

Might not some wise caviller, said the Marchioness smiling, gravely object, that the book which first received the red, and afterwards the blue rays, was wrote in English; and that in order to prove the different refrangibility, it was necessary for it to be Italian? But after all, it is an in-

famous thing to be so hardened against truth. Are not these experiments sufficiently decisive? And can there in any country of the world be assigned a cause, why the image of one colour should be nearer to a lens than that of another, unless it be the different refraction which they suffer in passing through the lens? Do not put yourself in a passion, Madam, said I; the different refrangibility will be true, notwithstanding these objections. You may still safely believe it, as many other judicious persons do, in defiance of that obstinate war which the antagonist of our philosopher declared against it. The Newtonian system had the same fortune as that field where Hannibal encamped when he besieged Rome, which did not sell at all the worse upon that account: or rather, you may look upon these objections, as the satirical verses, those miserable invectives which the licentiousness and malignity of the common soldiers mixt with the acclamations and glory of a Roman triumph. The beauty and simplicity of this system did not deserve to pass unmolested by envy and censure, that tax which merit is bound to pay to the public.

A celebrated minister * at once capable of the sublimest projects and the lowest employments, and a whole college, joined their forces against the applauses paid to the Cid. For a like reason, Moliere's Misanthrope was recited to the same audience that listened to the sermons of Cotin. How often have the celebrated Coracci had the mortification of seeing their fine pieces sold in their life-time by the ell, if I may use that expression, which now are the ornaments of the best chosen galleries, and paid by the ad.

* cardinal Richelieu.

miration of connoisseurs, better than by the gold of the rich !

It was necessary for the honour of Sir Isaac Newton's system, that it should be attacked on all sides, and that some should dispute the different refrangibility of the rays, while others wrangle about the immutability of colours, which is another of their properties discovered by our penetrating philosopher.

The experiment, upon which this new quality of colours is principally founded, was renewed in France, by monsieur Mariotte, a man exceedingly well versed in the arts of observation. This experiment in his hands produced an effect contrary to what Sir Isaac Newton had given reason to hope for. Thus a system, the slow and considerate offspring of reason and experience, was esteemed imaginary and vain; and a great philosopher, who spent his whole life in the study of truth, passed for a reveur, or an impostor.

What is this you tell me, said the Marchioness, of an experiment in France contrary to that of Sir Isaac Newton? Is it possible, that two men equally attentive, and accustomed to observation, should need a third to decide a matter of fact? It is not surprising that two people should reason differently upon the circumstances of a fact according to their different principles, as in the case of a person, who shifted his linen three times a day, one asserted that he must be extremely neat, and the other, that he was a very sloven. But to dispute and mutually deny the fact itself, I always thought reserved for silly women and enthusiasts,

It is certainly, answered I, a great reflection upon philosophers, when we find them dissent in matters like these;

it at least demonstrates, that one of them must have been inattentive in observing the laws of nature. Those rational horses so far superior to us men, which Gulliver discovered in the island of the Houyhynms, the last place where he arrived at in his allegorical voyages, were extremely surprized to find such contradictions among our philosophers, that is, those of our species who take the most pains to cultivate their reason. Those happy animals know not the meaning of uncertainty and doubt, in matters of fact. The dishonour that philosophers receive upon this account is very great, even among us, and there are too many examples of it.

Two famous academies, which have equally truth for their end, and emulation for their companion and guide, disputed upon a fact, by which is demonstrated the refraction which light suffers in passing from a vacuum into air. That academy, which maintained the refraction, was at length victorious; and it was necessary that even this truth should be contested in order to be admitted. Some from experience will tell you, that in breathing, the air passes from the lungs to the heart, while others allege the same experiment to prove that it does not. Many discover certain little machines and organizations in the glands of a body, which others affirm cannot be seen. Fancy and prepossession have the same influence here as in all other things, and make us think we discover in objects, without us, what runs strongest in our own mind. Thus a few irregular strokes will appear to the eyes of a painter, the contour of a leg or a face, wind-mills become giants to Don Quixot, and firs and beeches seem transformed to a fine lady in the eyes of a lover.

An observer must not search into experiments, in or-

der to find his own opinions there, like that person who looked for his pedigree in Homer, because both the one and the other will every where meet their own imaginations. Natural philosophy, like poetry, requires a man formed expressly for it, a Malpighi, a Reaumur, a Boyle, not moved by authority, seduced by fancy, nor terrified by difficulties; a man, if we will believe a celebrated writer, dexterous, active, and curious as the French and English, and reserved, cautious and circumspect as the Italians and Spaniards. Why not the patience of some other nation, said the Marchioness, instead of the caution of ours, which is too like diffidence to redound greatly to our honour. This author, answered I, considers only the good qualities of different nations. But you would be better pleased, perhaps, if the part we contribute to the formation of a perfect philosopher, were the religious attention of our passionate lovers. I am acquainted with one of these, said the Marchioness, who would be a Newtonian if philosophy was his mistress.

This attention, answered I, might carry these gentlemen to a great height of superstition, as it does a naturalist, who prescribes it as a rule of art, whenever an experiment is made, to mark exactly the country, hour of the day in which it was effected, what wind blew at that time, the degree of heat, and draught of the air, with many other circumstances of this nature, which in some cases may be proper, and even absolutely necessary, but in others I really do not see of what service they are; for in looking upon a paper of two colours with a prism, it is of no sort of importance whether the wind blows east or west, whether the time of the year be autumn or spring, the seventh or twentieth day of the month. These circumstantial na-

turalists resemble an antiquarian, who should copy a cornice of an inscription with as much exactness as the inscription itself.

Phyfic, replied the Marchioness, has almost divested itself of the prejudice of observing certain seasons of the moon as a proper time to apply its medicines; and perhaps natural philosophy has assumed it in her stead, that these superstitious notions may not be destroyed, but there may always be pretty near an equal dose of them in the world.

It must be confessed, however, answered I, that there may always be hoped some good effects from this diligent disposition, even though it be carried to such a degree as to become ridiculous: but we can never expect any good from negligence. You will see an evident proof of this, in that celebrated experiment of Sir Isaac Newton, before which all the antient idols of optics fall to the ground; those imaginary systems which supposed colour might be changed by refraction, reflection, the confinity to shadow; and in short that colour is nothing but a certain modification, as they express it, of light, which may easily be changed by these circumstances.

But Sir Isaac Newton has shewn the falshood of this opinion, and demonstrated that a ray, for example, red, well separated from all the rest, will constantly keep its colour in spite of any refraction or reflection it is made to suffer, or any other method that the fruitful invention of a naturalist can contrive to torment it. The same constancy will hold good in all the other colours, if they are well separated. The grand experiment which furnishes us with these agreeable and surprizing truths, is this which follows.

The image of the sun formed by the conjunction of a

prism and lens, is received upon a paper; by this conjunction the colours are much more unmixed and better separated than they would otherways be.

Having thus made a more perfect separation, the rays of different colours must pass successively through a hole in the paper, that they may be refracted by a second prism, in order to prove whether this new refraction can produce any new colour. If it should, we must confess that colour is nothing more than a certain modification which the light acquires in passing through the prism; and then philosophers may set their imaginations to work, in order to find out what motions, figures, and the like, are necessary to produce this modification.

But on the other hand, if the ray constantly preserves its own colour without the least alteration, we must agree that refraction has no share in the production of colours, and abandon the antient system of modification: and all its ingenious delusive dreams will vanish at the rising morn of the Newtonian truth.

Now the experiment we are upon, demonstrates that a homogeneal ray, red, yellow, blue, or of any other primary colour, is not in the least altered, by a new refraction, nor even by a great number of refractions which it is successively made to suffer. It is not changed either in its colour or degree of refrangibility, which remains constantly the same. Thus, if two rays, one red, and the other violet, be made to fall one after another upon the second prism, with the same incidence, that is, if both the rays coming from the same point, fall likewise upon the same point of the prism: if the rays, I say, fall upon the second prism in this manner, the violet, after the second refraction, will strike the opposite wall in a situation higher

than the red, and the intermediate colours in intermediate situations, those which had suffered the greater refraction in the first prism, suffering the greater in the second likewise; all these colours will paint upon a white paper directly opposite to them, a little circle perfectly round, and not oblong like the image made by the first prism, and this circle will be of the same colour as the rays, without any addition or mixture.

I beseech you to stop and take breath, said the Marchioness; you were engaged in such a long period, that I began to think you would never come to the end of it. I should be sorry, Madam, answered I, if the length of the period has rendered me obscure, and made you loose so fine an experiment. No, no, said the Marchioness, I understand it very well. Does not all your meaning amount to this, that the homogeneal rays of light are immutable both with respect to colour, and degree of refrangibility? I am extremely rejoiced, said I, to find I may be as prolix in my periods as I please, without apprehension of obscurity, and may employ one as long as those of the Azolain dialoguists, to tell you that this is the experiment which Mr. Mariotte endeavoured to make, and by some misfortune found, that after the second refraction certain new colours were united to the red and blue. I know not how this happened, but probably it was from some defect in the prism which he employed.

The ill success of this experiment would have done the immutability of colour no small injury in the learned world beyond sea, if it had not been repeated in England before some learned Frenchmen, the motive of whose voyage was purely philosophical. This repetition of the experiment clearly demonstrated, that Mr. Mariotte, though other-

wise an accurate observer, has failed in some of the circumstances necessary to bring it to good effect. Thus were these two nations, more divided by their different ways of thinking, than by a little arm of the sea, reconciled upon this point.

This law of nature common to all nations acquainted with light, met with a less favourable reception in Italy, than in any other. The most obstinate antagonists of the Newtonian system have risen among us; there seems to be some fatality in this, that a nation which the Italians once found so difficult to subdue by force, should in its turn find us the most difficult to be subdued by reason.

In order to contribute my share to the establishment of this law even among us, I caused the same experiment to be repeated at a place in Italy, celebrated for the learned men it has always produced, and neuter enough not to be suspected of partiality. No minister of state, said the Marchioness, could act more politicly in the choice of a proper place for the holding a congress. Within a very little, answered I, all my politics would have signified nothing: for though we made use of Sir Isaac Newton's own method in separating the colours, and the chamber was extremely dark, yet a certain light of a blewish cast always mixt itself with the colours refracted by the second prism. It is true, this light was irregular and inconstant, but however, it was sufficient to serve for an excuse to the incredulous.

This appearance give us a real inquietude: and we would never have slept in peace, if we had not, after much study, found out the cause. We observed that the borders of the coloured image were not so well terminated as they ought to have been, provided the prism, by which

it was coloured, had been good. We discovered a light, round the edges, of the same nature with that which was observed to be mixed with the colours refracted the second time, and we perceived that several streaks of this light crossed the image from one end to the other. From all these circumstances it appeared, there must be several irregularities in the prism, as bubbles of air inclosed in the glass, unevenness in the surface, and other things of the like nature, which were probably the reason why the light was irregularly refracted, and by this means rendered it impossible for the colours upon the image to be perfectly separated.

Various and repeated experiments made it evident that the fault of this apparent alteration of colours, which we observed in the image, must be imputed entirely to that irregular light which we had before suspected to be the cause, if we may call that an alteration which was nothing but the addition of one colour to another.

I congratulate you, interrupted the Marchioness, that after such a discovery nothing will hereafter disturb the tranquillity of your sleep. Heaven preserve me, answered I, from that cold tedious tranquillity, which is however the object of our desires. It is in philosophy as in all other human affairs, where the accomplishment of one desire often gives birth to another.

When we had discovered the cause of this defect in our experiments, our next business was to find some remedy for it. The difficulty of acquiring it was a new motive for our labour and inquietude.

Our prisms in Italy are of no other use than to amuse children, or hang up as a fine show in some window in the country, and not for the service of philosophers, who

are often too exact for artificers, and require a greater accuracy than is in the power of art to bestow.

We resolved to write to England, which has its Fawkeners for lapidaries, and its Grahams for clock-making, where, in short, every thing seems to be contrived for the service of the most curious and importunate naturalists, if fortune and our good genius had not unexpectedly furnished us with some which were just arrived from that country. These we esteemed as sacred, as the Romans did the ^{Anglic} article or shield which fell from heaven in the reign of Numa; and we could have wished for a Mamurius to make as many copies of these as he had formerly done of that.

With one of these prisms we renewed the experiment, and the coloured image, painted by it, emerged so beautiful, so well terminated, and so lively, that the other seemed no more, when compared to this, than a rough draught to a finished picture. The colours refracted by a second prism remained so immutable, that neither the most penetrating eye, nor even the *Zoilus* of the Newtonian system would have discovered the least alteration.

Perhaps, said the Marchioness, nature has reserved the merit of demonstrating truth to the English prisms, that is, to whose by those means she at first discovered herself. It would be a curious phenomenon, answered I, to observe such a partiality in nature, as for her to prefer such a prism made in London, to one produced in Murano. But the truth is, that if we consult her as we ought, she always answers the same, whether the prism be English or Italian, provided it be good and well worked; and the chamber, where the experiment is made, extremely dark.

If all these circumstances are rightly prepared, the colours, though refracted three or four times, will remain unchangeable, neither more nor less with regard either to colour or figure, than an object exposed to a homogeneous light, and viewed through a prism. The variety of colours, the change of figure, and the confusion discovered in objects looked upon in this manner, proceeds from nothing but their reflecting more or less all sorts of rays, which, being afterwards differently refracted, produce all these irregularities.

If upon a circle of paper there fall at the same time the red of one image and the blue of another, so that the purple colour, composed of both these, may appear, it will, when examined through a prism, seem divided into two separate circles, the one red and the other blue; and the reason of this appearance is the different refraction of these two colours. If the yellow and green of two other images should fall at the same time upon the paper, so that it would be illuminated with four colours at once, it will appear oblong and divided by refraction into as many circles as there are colours, and these circles will seem placed upon one another. I know you are going to add, said the Marchioness, interrupting me, that if this paper be exposed to the light of the sun, who contains every sort of ray in himself, it will appear of a figure still more oblong, and painted with the colours of the rainbow; whereas, if it be illuminated by only one homogeneous light, it will alter neither its figure nor colour, when observed through a prism.

You must forgive the weakness of human nature, Madam, answered I, if we generally finish the sentence we have begun. It was reserved for Sir Isaac Newton and you,

to understand nature by half a word, and find out natural philosophy, notwithstanding its uncertainty. It is superfluous to tell you that flies and other little objects, placed in a homogeneal light, appear very distinctly to the eye with a prism; and the very smallest Elziver print may be read without any difficulty; but the same things will not have this effect, when placed in the heterogeneous light of the sun, because of the confusion and quantities of colours that arise.

In this case I abandon the prism to the disposal of poetry, to make use of it in comparisons, which do it no great honour. That celebrated author, whose fine ode you so much admired, compares it to false eloquence, which obscures the face of truth, lavishes its ornaments without distinction, and diffuses its glaring colour over every thing. It is certain that the poet, in this comparison, means that prism which transmits the rays of every sort. And when it transmits only the homogeneal rays, said the Marchioness, may we not compare it to true eloquence and true spirit? For as it shews us the objects removed out of their place without any alteration, so true wit often surprises us only by varying common subjects in a new manner.

You are so well acquainted with the prism, answered I, that you may safely compare it with your own wit. But I know not what comparison you will find for the immutability of colours, unless you seek for it perhaps in your own heart; and then knowing that reflection has no more influence on that immutability than refraction has, you will be better acquainted with it than you at present are.

If the colours with which bodies are variegated and painted were only a modification, which the rays of light acquire by being reflected from their various surfaces, as

was once believed, a body which appears red in the light of the sun, would still remain red when placed in any other colour of the painted image, for instance, *blue*, because it could modify this blue colour refracted and modified already by the prism, as well as it does the light which comes directly from the sun.

But Sir Isaac Newton has proved by experiments, that every body placed in homogeneous rays is of the same colour as the rays themselves, without allowing, however, the supposition that bodies by reflection modify the light in such a manner, as to make it receive this or that particular colour. Thus all white, red, yellow, blue, green bodies, as paper, scarlet, gold, ultra-marine, and grass, in red rays appear totally red, in blue, totally blue, and so of the rest. The only difference consists in this, that all these various bodies, placed in the same homogeneous light, are not all equally luminous, but every body appears the most lively when placed in a light of its own colour, except paper, and all other white bodies which equally receive any colour, and may be regarded as the *Cameleon* and *Proteus* of optics.

Would this diamond then, interrupted the Marchioness, if placed in the rays of our coloured image, take indifferently any colour, and at one time be transformed to a ruby, at another to a topaz, an emerald or a sapphire? So much the better, answered I, as it would dart only one unmixed colour, and all the varying splendors with which it sparkles in the direct light of the sun, would vanish in this homogeneous light.

It is very pleasant to observe how the fine dust or atoms in the air change colour as they pass from one ray to ano-

ther, just as a river varies in its colour according to the various qualities of its bottom.

Other bodies, as I before mentioned, are not equally lively when placed in different coloured lights. The varnish, for instance, with which Martino, the emulator of the Chinese art, makes so many fine curiosities, is extremely luminous in the red light, less in the green, and still fainter in the blue. On the contrary, the Lapis Lazzuli, which has the honour to serve for a repository to your snuff, is extremely lively in the blue, less so in the green, still fainter in the yellow, and almost dark in the red.

The same inequality holds good in bodies seen by a transmitted light, as is proved by glasses of different colours; so that every body reflects or transmits, in great abundance, those rays which are of its own colour, and reflects or transmits the other rays, in proportion as they are nearer or farther off its own colour in the order of refrangibility.

It follows from hence, said the Marchioness, that no colour even that seems the most perfect, can be absolutely unmixed. And perhaps it will never be in the power of art to dye a silk in such a manner, as for it to reflect only one sort of rays.

It would be more difficult, answered I, to sort the various colours together, and flatter our sight by the concords of harmony, if they were all homogeneal and unmixed. In this case, all the delicacy of nature would be requisite to find out the innumerable intermediate shades betwixt any two colours. But now as every colour is more or less blended with some other, we are by that means furnished with a more easy and expeditious way.

Hence it is that the gradation from one shade to ano-

ther, though perhaps there may be several intermediate ones wanting, does not appear defective to our eye, which discovers in each the same basis of all the colours that softens them, and serves for a support to the harmony.

There would arise other inconveniencies besides these, if coloured mediums did not transmit every sort of ray; for this would aggravate a distemper bad enough in itself, which infects and tinges the whole body, and the eye itself with an unpleasing yellow.

Persons under such circumstances as these, when it is very improper to pay visits to ladies, would become absolutely blind, unless to yellow objects, and could see no faces but of those who are troubled with the same disorder.

A perfectly complaisant lover, replied the Marchioness, if his mistress should happen to be ill of this distemper, must clothe himself in yellow, a colour, which, though regarded with great veneration in China, is not looked upon as a good omen for lovers among us; and perhaps get the jaundice in order to be seen by his charmer, and give her a proof of his affection.

So perfect a lover, answered I, would not be an improper person to prove this immutability of colours, if we had no more proofs to demonstrate it than what you have already seen. What remained to be shewn was, whether the confines of shadow, with which the light is bounded, are capable of making any alteration in the colours? This would have been fine sport for those naturalists who lay hold on every thing, in order to build a system.

Our philosopher put the colours to the test of this new experiment, and found nothing wanting in their constancy which maintains its ground, even when it happens that rays of different colours cross and intersect each other; it

appears, in short, to defy every thing judged capable of bringing any alteration upon them.

We must have recourse to romance, said the Marchioness, to find some equal to these colours, which do not give place even to the *Epheſian Anthia*, a model of the firmest and most obstinate constancy, in spite of all that a romancer can produce to make her at length — What? answered I; resemble the matron her fellow-citizen, replied the Marchioness. The constancy of these colours must certainly appear very surprizing to ladies, answered I. I do not doubt but the greater part of them would much sooner admit the system of Lucretius, who without so many experiments, affirmed not only that they are mutable, but that any one colour may be changed into all the rest.

D I A L O G U E V.

Exposition of the Newtonian philosophy continued.

THE next morning, as soon as the Marchioness was up, she sent for me into her closet, not concealing that agreeable disorder which she knew her beauty could receive no injury from. I find indeed, said she, that your philosophy begins to grow a very serious thing. I can assure you, I have slept much less this night than before; I cannot tell whether this be the reason of it, but I find that philosophy and sound sleep do not agree very well together. My interrupted dreams have transported me into the region of optics, where I saw nothing but prisms, lenses, rays differently refracted, coloured images; in short, all those experiments, and all that philosophical apparatus which you described, arose successively in my imagination, like visions and fancies. Whatever charms these things may have in themselves, I could never have imagined they would employ my thoughts so strongly at a time when it is not very customary to think of philosophy. No really, answered I, it was a time more proper to think on the philosopher. You are not to suppose, replied the Marchioness, but he had his share, and has no reason to complain of me. If this be the case, Madam, answered I, there is no great mischief done. I rather advise you to recal these dreams to your memory as often as you can, and you will be still the more sensible that they deserve it. How do you suppose it possible, continued she smiling, that I could think on these experiments without admiring the penetration and ingenuity of the philosopher who invented them.

a man who seemed directed by nature herself, in the method of tracing her laws? I perceive, said I, that you take the thing too seriously. In the present case I think you might be contented with the expositor. How! can I be too serious? replied the Marchioness. We are examining whether colours be immutable or not, whether the rays of light be differently refrangible; we are building up and throwing down systems, and in short, our inquiries aim at nothing else than truth itself. Can you reasonably accuse me then of being too serious in matters of such importance? But these systems, answered I, and this truth, however pompous they may sound to the ear, ought not, however, to disturb our more agreeable dreams. It would really gain me a fine reputation in the world, if it were publicly known, that I had made you dream of lenses and prisms. We should act in things of this nature, as those, who study to make the best use of their passions, do with regard to love. These persons, who do not appear to be the most injudicious, never devote themselves so entirely to it, as to interrupt their more important concerns, but only as much as is sufficient to make them pass away two or three hours agreeably with that sex with whom it is hardly possibly to converse upon good terms, without at least a pretence of being in love.

You at once give me lessons in love and philosophy, replied the Marchioness. But you know when people first fall in love, they have little leisure for these grave reflections, but suffer themselves to be transported farther than they ought. This is exactly my case with regard to philosophy, in which I have hardly yet advanced one step. I am so little mistress of myself, that I have gone so far as to seek methods to confirm Sir Isaac Newton's system. Af-

ter all you have told me, judge whether my transports were not very strong.

Let us see, Madam, answered I, what they have produced, for we often owe the finest things to strong passions. The Iliad, Æneis, the poems of Dante and Milton, were produced in their most vigorous time of life. To these may be added, at least for that veneration with which they are regarded by their countrymen, the Lusiade of Camoens, composed in a time of the greatest revolutions and conquests in Portugal, and the Araucana of the Spaniards, where the poet himself is the hero. Perhaps between the broken slumbers of last night, your imagination produced something greater than all I have been mentioning.

I am afraid, answered the Marchioness, that it will amount to very little. I was thinking, that if light is composed of rays of different colours, which, blended together, produce *white*, we ought to examine whether these colours, after being separated by the prism, might not be mixt together again. I for a long time considered, but with little success, in what manner this could be effected.

Sir Isaac Newton himself, said I, has delivered you from this trouble; for that method of confirming his system which you mention is so good, or rather so evident and immediate a consequence of order, that he has made several experiments to that purpose. I am now going to shew you one of the most celebrated, and at the same time the most simple, to which this great philosopher was conducted by that spirit of order which you possess in common with him.

The image of the sun made by a prism in the dark chamber, is received upon a convex lens, that the coloured ray, which at going out of the prism, diverged, may by

the lens be made to converge and unite, and by this means be again blended together. I am quite ashamed both of my stupidity and myself, interrupted the Marchioness. I had all the materials necessary for the execution of my idea, ready prepared to my hand; they only wanted putting together, and I had not the sense to do it. You are greatly in the right, to be unwilling that a person should hear the voice of philosophy, who is incapable of making it an answer. I might rather, answered I, apply to you that famous saying of antiquity, *I wish with all these qualifications, you were one of us*. You will find in optics themselves, some consolation for what you call your *stupidity*. Men, those reasonable and curious beings, lived above three hundred years before they found out that a convex and concave glass put together, would make a telescope; and though they had the materials every day at hand, were at least indebted to mere chance for this useful instrument. It was a greater disgrace to mankind not to discover it before, than honour to them that they found it at last. So that this useful and fine invention is of the number of those which are standing monuments of the weakness of human nature. You comfort me, replied the Marchioness, at the expence of mankind. — But to return to our subject. I suppose that point beyond the lens, where the coloured rays are united, will appear totally white.

The rays, answered I, have no sooner passed through the lens, but they begin to mix and efface each other; and they lose the fine harmonious proportion established betwixt them in the spaces of the coloured image, the original of the music of the eyes. When they are all confined at length, and incorporated together in the focus of the lens, they form a little circular image totally white, a re-

public, if I may use the expression, of colours, where they are all equally tempered together: The red can no longer display its lively flame, the green boasts no more the smiling livery of the spring, nor the blue the lucid robe of heaven, but all, blended together, restore the whiteness of the sun from whence they came, in such a manner, however, that as they recede from the focus, they again renew their splendor and colour, but in a contrary order, and the ravished eye again wanders from one pleasure to another.

You will easily understand how they came to be inverted, if you remember the two sticks crossed together, mentioned by Des Cartes, which you once believed to have a greater efficacy in explaining the phenomena of optics, than they really have. The appearance that the colours again make beyond the place where they were blended, demonstrates that the rays lose neither their colour nor quality, as some might perhaps believe, but that the whiteness, which happens in the focus of the lens, is produced only by their mixture.

I now understand, said she, what you meant yesterday by saying, that the immutability of colours still remains, even when rays of a different colour intersect and cross each other; for if it were otherways, we should not see the prismatic colours re-appear beyond the place where the rays united.

This is the very experiment, answered I, upon which the immutability of colours was grounded; and all the experiments of Sir Isaac Newton have this peculiar and admirable quality, that each single one is not contented with demonstrating only one thing, as in the case of most others, but demonstrates many more at the same time. This

arises from the close union, and almost geometrical connexion which the properties of light have between themselves.

Sir Isaac Newton's experiment, said the Marchioness, seems to resemble the battles of the antients, which often gained the victor a great number of provinces at a time. And those of most other philosophers, answered I, the battles of the moderns; the most noisy preparations, the most consummate contrivance, and the blood of millions, amount to no more than the taking a place, which perhaps might have surrendered in two months by treaty.

But to return to your experiment. I call it *your's*, because though you did not invent it, you saw the necessity there was for its invention, in order to complete the system. Our philosopher never quitted it till he had varied it a thousand ways.

It was necessary to prevent some one of the coloured rays from passing through the lens, in order to see whether the whiteness of the little circular image would by that means be changed.

This Sir Isaac Newton did, and intercepted the passage, sometimes of one colour and sometimes of another; and the whiteness ceased, and degenerated into that colour which arises from the composition of those colours which were not intercepted, but suffered to pass through the lens.

The want of any colour in the circular image, which is not suffered to pass, will be very agreeably discovered by looking through a prism, which resolves the image into its component colours, by giving them a different refraction.

If all the rays be transmitted through the lens, the

image will be white; but viewed through a prism, it will appear of all colours like the rainbow: if any ray be intercepted, this by the prism was discovered to be wanting in the image, till at last suffering only one colour to pass through the lens, this one colour too was seen by the prism.

If all the colours were successively intercepted by the teeth of a comb made to pass very swiftly over the lens, the circular image would remain white, and the different colours not be distinguished, by reason of the quick impression which they all successively make upon the eye.

You may perhaps have observed, that when a light torch is moved nimbly round in a circle, the whole circle which it forms in the air, appears on fire; and the reason of this is, because the sensation, which in the several places of that circle it raises in the eye, remains impressed till the torch returns again to the same place.

In the same manner, when the colours follow one another with an extreme rapidity, the impression of each of them remains in the eye, till a revolution of all the colours be completed. The impressions therefor of all the successive colours are at once in the same part of the eye, and jointly excite the sensation of whiteness there.

The same was afterwards proved by a wheel, whose circle, painted with the several colours of the prism, appeared white, when turned very rapidly round itself.

I must confess, said the Marchioness, that even if I could have found the experiment I sought for, I should never have been able to diversify it to many different ways, though the inconstancy which you, gentlemen, lay to our charge, might perhaps have given me no small assistance.

This inconstancy, answered I, which perhaps is not so

great a defect as some believe, was not wanting in Sir Isaac Newton. With the most fertile, and almost poetical imagination, he continually invented new experiments, which, though different from each other, all concurred to prove the same thing. They seemed to rise under his hands as the poets make flowers spring under the feet of their beauties.

The coloured image, formed by the prism, becomes white, when viewed through another prism, in such a manner, that it contracts the image and mingles the colours. I have observed the same phenomenon in the rainbow, which is the effect of a separation of the solar rays in the drops of rain opposite to the sun. It appears white, when viewed through a prism, turned in such a manner, as to contract it and blend the colours together.

Those who live near the cataracts of rivers, see a rainbow every day, when the sky is clear, formed by the sun in the dashing of the water against the rocks; making people have the opportunity of seeing this experiment much oftener than we can.

I would, if possible, replied the Marchioness, have nothing to envy others. Though we have no cataracts, a fountain will imitate the rain, present us with the colours of the rainbow, and we may make our observations at pleasure. We will call this fountain, if you think proper, *The fountain of optics*.

Till your garden furnishes you with proofs of the Newtonian system, answered I, as the gallery did with objections against the Cartesian, you may return to the dark room: there you will see that the whiteness of a paper placed over against the coloured image of the sun, does not suffer any alteration, if it be placed in such a manner as to partake

equally of all the colours; whereas, if it approaches nearer to one than another, its whiteness will be tinged with that colour which is next it. Is it possible now for truth to descend from heaven with a more shining train of proofs?

I was very confident, said the Marchioness, to venture my thoughts upon a thing, which cost Sir Isaac Newton so much study. How is it possible I could ever have found out the very least of these experiments, as easy and simple as they now appear? But in exchange, answered I, you can easily invent things that perhaps would have puzzled the philosopher. It is much more proper for you to know in what proportion to mix hope and fear, smiles and frowns, to prevent a lover's passion from growing languid, than to be exactly acquainted what quantity of different coloured powders is necessary to be mixed together to form a white. This is another experiment which our philosopher tried, that there might be nothing wanting to confirm his system. It is true, the white which arises from this composition, is dusky, grey, and obscure like the colour of ashes; and the reason is, because the colours of these powders are too imperfect and faint, compared with those of the prism, to make a lively clear white.

However if this mixture be exposed to the sun, in order to increase the force of the light, that dusky obscure white will become bright and clear, though it will never equal the strength of the paper exposed to the same light.

For this reason in coloured prints, one of the finest inventions of our time, which, with only three colours, perfectly imitate all the variety of painting, the paper is left uncovered for *strong clears* and *whites*.

Water thickened with soap, and agitated so as to raise a froth, is more proper to demonstrate that a composition

of colours produces white. After the froth is a little settled, there will appear upon the surfaces of the bubbles of which it is composed, different colours, which when viewed at a distance cannot be distinguished from each other, and the whole froth will appear perfectly white. This experiment has, beside its being an agreeable one, this further advantage, that it is very easy to make.

Philosophy, said the Marchioness, from what I can discover of it, is like a game of chess, which upon any other occasion I should make no scruple to call an ingenious pretext to waste time. The very last piece in the one, and the least experiment in the other, is often of the highest importance. A pawn, in the hand of a skilful player, may give check mate, and a little froth will furnish Sir Isaac Newton with a whole magazine of observations and discoveries. Half the world that preceded him had the same bubbles and froth before their eyes, without so much as seeing them. The antients themselves would a thousand times have observed and neglected them.

The eyes of the antients, answered I, were much better able to judge of the elegance of a statue or a temple, than the importance of an experiment. Seneca was acquainted with a sort of prism, which, receiving the light of the sun on one side, displayed to the eye the colours of the rainbow. All the explication which he gives of this phenomenon is, that there is really no colour, but only the appearance of a false colour like that on the neck of a dove, which appears and dis-appears according to the motion of the eye and the change of its situation. This fine explication sufficiently shews how very little the antients studied nature and pursued her steps; for if Seneca had taken the least trouble to examine his prism, he must have seen the

difference between the colours produced by that, and those on the neck of a dove.

A particular sort of microscope known to this philosopher, and which perhaps the antient artificers made use of in the curious engraving of their intaglia's and cameo's, the enigma and admiration of our time, this microscope, I say, composed of a ball of glass filled with water, had no better fortune in his hands than the prism. He ascribed the magnifying of the objects viewed through this glass to a quality of the water, and not to the figure of the glass which contained it.

The weight and other properties of air were known to the antients; and in order to explain how water ascends in a sucking pump, which is occasioned by this weight of the air, they had recourse to a certain imaginary horror that nature has for a vacuum: So that rather than leave the smallest space empty, she chose to violate her own laws of gravity, and make the water ascend. And as one folly produces a thousand more, the great horror that nature testified for a vacuum in this pump, extended only to a certain height, and beyond this perhaps was changed into love, for there she admits as great a vacuum in the pump as you could desire.

But to quote still more examples — Nero in his golden palace, one of the most magnificent effects of despotic power in the universe, erected a temple of stone so very transparent, that day-light entered into it even when the doors were shut. Pliny who gives us this relation, instead of contenting himself with affirming that it was more transparent than Alabaster, says, that it did not transmit the light like other pellucid substances, but included it within

itself: if this had been the case, the temple must have appeared much more luminous by night than by day.

The antients were fonder of what raised their admiration than increased their knowledge; and perhaps thought experiments, which are the only method by which we can arrive to a true admiration of nature, were too immaterial to imploy the attention of a philosopher, who ought to consult nothing but reason. They never imagined these experiments would one day lead industrious posterity to such an exactness as to subject flame to the examination of a balance, which was antiently regarded as a light substance, for whose sake they invented a particular sphere of fire where it was affirmed to ascend.

Nor could they foresee that these experiments could help us to calculate how much we daily lose by a continual insensible perspiration, how many million tuns of water the Mediterranean sea perspires in a summer's day, how much a man decreases by the weariness of the muscles from morning to night? In short, that they should inable us to counterfeit nature herself; and by certain chymical mixtures emulate her *Ætna's* and *Vesuvio's*, and imitate her thunder much better than their own rash *Salmonæus*?

If an antient had been asked whether the phosphorus of Bologna, for example, shines by its own light, or by a borrowed one, it is impossible to know how many ridiculous fancies they would have uttered by consulting reason; whereas a modern with a single experiment has put the matter out of all question. Pray, what is this *phosphorus*, said the Marchioness, this subject of the absurdities of the ancients and experiments of the moderns? It is a certain stone, answered I, found in a mountain near Bologna, which, calcined with fire, acquires the property of shining

in the dark like a coal, if it has been exposed a little while to the light of the sun, or only to the open air. From this quality it has obtained the fine Greek name of *phosphorus*, which signifies a lucid body. This is an honour given almost to every thing appropriated to learned uses.

An etymologist could not perhaps give a better name to this place than that of *phosphorus*, which in our language signifies the Lucid hill, and would thus consecrate it forever to philosophy and learning. We are much obliged to your scholar, said she, for conferring so fine a name on this place which certainly deserves it.

The question, continued I, is at present reduced to this, whether the *phosphorus* only takes in and imbibes the light to which it is exposed, and from thence carried into the dark, shines with a borrowed light? or whether the external light puts its parts into such an agitation as to kindle a light which it contains within itself, which by this means loosed from its prison, if I may use that expression, emits itself from the phosphorus, which in this manner shines by its own light? This last supposition is more honourable for it, and better agrees with the fine name it bears.

In order to decide this point, a modern philosopher chose a sort of light which would shew whether the phosphorus, when exposed to it, imbibed any of its rays, and by that means reveal the theft of this new *Prometheus*. I already see, interrupted the Marchioness, how this modern proceeded. He placed the phosphorus in one of the colours of the prismatic image, in order to see whether it would acquire the colour as well as the light: if it did actually take the colour, it is evident that it imbibes the external light, and shines with a splendor not its own: but if it does not take the colour of the image, since colours

are immutable and suffer no alteration, the light only agitates its parts, and as you express it, loses its splendor out of prison; and thus the phosphorus shines not by a borrowed lustre but its own, and ought rather to be compared with the sun himself, than Prometheus.

It is too true, answered I, that fine ladies can be just what they please. You would be extremely in the wrong, if you hereafter complain of any want of sagacity in physics. What you have been describing is the very method which the Bolognese philosopher took; and by this experiment he confirmed to his fellow-citizen the phosphorus, the honour of shining by its own light. It is probable that the innumerable other phosphori of the same nature, lately discovered in France, owed their lustre to the same cause: these, by enriching philosophy with new wonders, have deprived the Bolognese of the honour of singularity, which it partook with only one other in the whole philosophical world. Do not diamonds, the most valuable phosphorus of nature, shine in the dark, because the external light kindles, and revives the internal light, of which they are a rich and inexhaustible treasure?

You may judge, replied the Marchioness, of my very great sagacity in philosophical affairs, when I never observed a phenomenon which I every day carry about me. Perhaps, Madam, answered I, you were never in a place dark enough to make this observation. Signore Baccari one day visited a lady in some indisposition, who was resting behind a screen far from the air, and in a place absolutely dark. The lady asked him whether he had not a light in his hand? which he denied; but she constantly insisting she saw something glitter, the doctor at last suspected it to be his ring which shone in that profound dark-

ness, and perceived he had a long time, without knowing it, carried the phosphorus upon his finger. You may judge of the value he afterwards set upon this ring. He made innumerable experiments with it about the time that Mr Du Fay, father of so many phosphori, found that diamonds had the same property. How empty and barren must the philosophy of the antients have been, said the Marchioness, and how copious, how charming is ours, whose observations enhance even the value of diamonds!

I will give you still greater evidence, answered I, how much the antients were to blame in their neglect of experiments, and you will be fully convinced that there is none even of those which seem of least importance, but what is of great service to natural philosophy. That froth we lately mentioned is an instance of this; for as little philosophical as it may seem to vulgar eyes, it was the principal thing by which Sir Isaac Newton found out the cause of those various and almost innumerable colours which we see in bodies.

He had discovered in general, that certain bodies appear of a certain colour, because they reflect one sort of rays more copiously than the rest, and other bodies of different colour, because they reflect a different sort; so that if light consisted of only one sort of rays, there could be only one colour in the world, nor would it be possible by refractions and reflections to produce a new one,

This discovery which would perhaps have satisfied any other philosopher, served only to excite the curiosity of ours, and was but a prelude to innumerable others.

Why should this silk reflect the blue more freely than any other sort of rays? The reason is this.

If one of those bubbles which are formed by blowing

water a little thickened with soap, be covered with glass in order to prevent its being agitated by the air, it will appear tinged with a great variety of colours, which spread themselves like so many rings one within another, and encompass the top of the bubble. And in proportion as the bubble grows thinner by the continual subsiding of the water, these rings slowly dilate and overspread the whole, descending in order to the bottom of it, where they all afterwards successively vanish.

The variety of these colours depends on the unequal thickness of the bubble of water in different parts. But how to determine these inequalities is not so easy, and perhaps would have been impossible to any but Sir Isaac Newton, who examined these rings a thousand ways, guided by his constant tutor geometry, and a spirit of observation, whose fertility seemed to increase in proportion to the difficulties it encountered.

He discovered that a certain determinate thickness is necessary in a plate of water, for example, in order for it to reflect a particular colour, and a different thickness to make it reflect any other colour, and in general, that a less thickness is necessary to reflect the most refrangible rays, as violet and indigo, than those which are least refrangible, as red and orange; all this is to be considered with regard to the substance of equal density. But when the density in one substance is less than in another, as the density of air compared with that of water, a greater thickness will be necessary in the first than in the last, to reflect the same colour.

After the same manner he defined the thicknesses necessary for the transmission of colours. From the analogy or similitude between the plates of substances which he considered, and the particles of which bodies are composed,

he demonstrated the difference whence transmission is different

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he demonstrated that their colours depend on nothing but the different thickneses and density in their particles, whence it follows that some are more proper to reflect or transmit the rays of one colour, and others those of a different one.

This analogy holds good in many instances. Thus the one and the other are transparent: the leaves of gold and the particles of many other bodies transmit one colour and reflect another, just as the bubbles of water which we have been mentioning: these rings appear of a various colour when viewed in different situations; the same happens in certain silks, in the fine web of the industrious spider, and as Tasso sweetly sings,

*The feathers so, that tender, soft and plain
About the dove's smooth neck clost couched been,
Do in one colour never long remain,
But change their hue 'gainst glimpse of Phæbus sheen.
And now of rubies bright a vermeil chain,
Now make a carknet rich of emeralds green,
Now mingle both, now alter, turn, and change
To thousand colours rich, pure, fair, and strange.*

FAIRFAX'S Tasso.

This appears very evident in those powders that painters make use of; for when they are ground, that is, when their parts are subtilised, their colours change a little. Bodies may in some manner be regarded as stuffs, for their threads, every one in particular reflecting a particular sort of rays, the whole stuff appears of that colour which is the result of all the rays reflected from the several threads of which the stuff is composed.

But what becomes of those rays which are not reflected, said the Marchioness? Can you give an account of them? They are either transmitted, answered I, or stifled and extinguished, and are thus lost among the particles of bodies. A leaf, of gold placed between light and the eye, is transparent, and appears of a greenish blue; but a collection of these leaves placed one upon another, loses both colour and transparency, the rays which pass through the first leaf being absolutely extinguished in passing successively through the rest.

White bodies, to continue our similitude, are stuffs composed of threads which reflect all colours; black, on the contrary, absorb and extinguish every sort of ray within themselves. For this reason, black bodies heat much more easily than any other; and a black cap, such as the English ladies wear in St. James's park, would not at all agree with your walks in the Italian sun.

White bodies, as they reflect and drive every sort of ray from them, heat with more difficulty than the others which imbibe and absorb the rays, and neither transmit or reflect them.

From the same cause arise the various colours which we discover in the air. The different density and thickness of the exhalations and vapours that rise from the sea and earth, paints the heaven with varying splendors, when rosy-fingered Aurora opens the portals of the morning, and calls back mortals to their several labours, or when Vesper invites them to an agreeable repose; it is difficult however, to trace a cause by which the colours at the rising and setting of the sun are almost all the same, and succeed each other in a certain order. But this we certainly know, that the several colours of different persons eyes

proceeds from the difference of texture in the iris, which is that coat in the eye that encompasses the pupil.

The variety of fibres in the iris kindles in some the imperious look of a black eye, in others, the insidious sweetness of the blue. But it is not easy to assign a constant cause, why the northern nations should generally have white hair and blue or gray eyes, and we of a warmer imagination, not in a warmer climate, should have our eyes as black as our hair.

This system, however, will give us the explication of a phenomenon which is perhaps inexplicable in any other, and will thus make us a compensation for not being able to give a reason for every thing in particular.

The phenomenon is this: two transparent liquors, the one red and the other blue, cease to be transparent when we look through both at the same time. This phenomenon which so greatly surprised the person who first observed it, is only a consequence of the Newtonian doctrine. The one of these liquors transmits only red rays, and the other only blue. Hence it follows, that the rays, transmitted by the one, will be extinguished and absorbed by the other, and the eye which looks through each of them receive none. And this phenomenon is one of those whose explication becomes a demonstration of the system which is capable of explaining it.

That opinion, said the Marchioness, that blind people can distinguish colours by their feeling, now begins to appear credible to me: or rather, is it not another system? If our feeling was finer than it is at present, as fine as that of blind persons perhaps is, could not we discover the colour of a body by feeling the different thickness of its particles? And thus we should effect by our immediate sense,

what a Newtonian would by his calculations, if any one should acquaint him with the hidden texture of bodies.

Your blind observers, answered I, might distinguish colours by their feeling, even in the Cartesian system which you have now given up. For according to that, there must be a difference in the particles of bodies of different colours in order that the rays of light may be differently modified. A proof like this you perceive is too ambiguous to deserve a place among those we have already mentioned; and there is the same defect in what is said of a singular kind of barometer, which the Chinese make use of to form a judgment of the weather by. This barometer is a statue placed upon a mountain, which foretells the changes of the sky and air, by varying its own colour.

But had we not better seek for a phenomenon nearer ourselves in the nation of gallantry and politeness, which can be explained by the English system alone? Why should the belles of that happy country lay on more red when they appear in the boxes at an opera, than when they embellish with their charms the agreeable walks of the Thuilleries?

You lead Sir Isaac Newton's system, said the Marchioness, into places where you would have found it very difficult to lead its author. Not if you, Madam, answered I, had been there.

The light of a candle is not so white as that of the day; it has a yellowish cast, and viewed through a prism, yellow appears the most shining colour in it. The less then the Spanish wool is charged, or in other words, the more it reflects other rays besides the red, the stronger will the yellow appear, which is the predominant colour in this

fort of light; just as in a chamber where the light enters through coloured curtains, the objects in the chamber will the more easily take the colour of the curtains in proportion as their own colour is weak and faint. This is evidently a reason why the quality of Spanish wool should be augmented for the opera, that neither the cheeks of the ladies, nor the eyes of their admirers, may lose any thing, but find the same advantages by the light of the evening as by that of the day.

In the Cartesian system, this wise precaution would be entirely useless; for if the Spanish wool can modify the light of the day, it would in the same manner modify that of the evening, be it of what colour it will.

Must it not be a mortification, said the Marchioness, for the ladies of this happy climate, if they ever have time to consider it, not to have a system in their own country able to explain this phenomenon in their vermilion, but be obliged to call a foreign one from beyond sea to their assistance? So much the more glorious is it for this to extend its empire over all nations, even so far as to give them lessons for the toilet. This is not the only one, answered I. If you would not have a blue appear green by candle-light, which might disconcert the harmony of a suit of cloaths, and cause innumerable chagrins, you must be careful to chuse it very clear, otherwise the blue rays mixed with the yellow, which the silk would reflect in greater quantities by candle-light, might perhaps make it appear green.

These are the gordian knots of the optic science, which this system dissolves without eluding the oracle. These phenomena, inexplicable to every other system, are without difficulty explained in this. Every ambiguous expli-

cation, every proof that has not the force of demonstration, is entirely rejected by the Newtonian philosophy.

An analogy, for instance, discovered between the production of colours and that of other things, which would supply another system with a proof, can serve only for ornament and luxury to this.

It has been lately discovered, that insects, men, animals, and plants, instead of being continually re-produced by nature, only unfold themselves from their respective plants or seeds, in which they are really contained, whenever they find a proper disposition for it; that is, both animals and plants wait for a proper repository, certain juices, degrees of heat, and other things requisite to unfold them. In the like manner, colours are, not as was once believed, produced at every refraction, or reflection, or some other similar cause, but unfold themselves, if I may use the expression, from the bosom of light, which contains them within itself, whenever it is refracted by a prism; or reflected from the particles of bodies. And this method of their production seems much more agreeable to the universal laws and established order of nature.

After the same manner appears the colour of the rainbow, the coloured circles sometimes seen round the sun and moon, and those of a certain light, which is often seen towards the northern parts of heaven, and called *Aurora Borealis*.

Whatever riches and magnificence, replied the Marchioness, nature has displayed in so great a variety of colours, she seems to have observed some frugality in their production. At least the Newtonian nature appears to me a better œconomist than the Cartesian. The first has made light a magazine and reservoir of colours, which she pro-

duced once for all, insusceptible of any alteration, only with a certain disposition that renders them capable of being separated from each other, and shewing us by this separation a colour, which, all united and mixed together, they could not do; whereas the Cartesian nature is every moment obliged to give new rotations to her globules, and at every refraction and every little circumstance, consider in what manner to vary them. This must be an infinite fatigue to her, and a very great application of thought.

But these dispositions, answered I, which the colours have to separate themselves, and which you so greatly admire, however convenient they may be to nature by sparing her so much trouble and thought, are sometimes very inconvenient to us.

Inconvenient! replied the Marchioness. Is it not to these we are indebted for the beautiful variety of the world? How tiresome and unpleasant would it be for us to see in all objects a repetition of the same colour! You apprehend it, answered I, to be a great evil always to see the world in *chiaro oscuro*, if I may use that expression, and to be obliged to be dressed always in the same colour, and what is worse, in a colour like that of your own complexion. You may add, replied she, the dread of losing a topic of discourse so very pleasing to ladies.

All these misfortunes, answered I, and this terrible addition of yours, would happen, if the rays had no disposition to separate from each other, or if they were all of the same colour. The Cameleon and wrinkled faces would be considerable losers too. Some of these, without the trouble of changing their skin, are discovered in the space of twelve, or at most twenty four hours to change their colours.

Astronomers, on the other hand, would gain no small advantage if the rays were inseparable and of the same colour. And what would not an astronomer sacrifice to determine the exact time of an eclipse of Jupiter's satellites, or to get a distinct sight of the occultation of a star by the moon? These are a set of people whose looks are always directed to heaven, and have very little regard to our earth any farther than she is a planet, and upon that account enters into the celestial system. This is all they regard in her, and therefor would feel very little concern if the ladies of this planet were under an impossibility of changing every day the colour of their cloaths, or subject to many other the like inconveniences.

But what opposition, replied the Marchioness, can there be betwixt the separability of the coloured rays and the observations of these gentlemen, to make them quarrel with us for the pleasure we receive from this variety? There is a great opposition betwixt them, answered I, and you will be soon convinced of it, when I tell you that the separability of the rays is prejudicial to the perfection of telescopes, which astronomers regard as their very eyes. I before positively affirmed that convex-glasses, of which telescopes are composed, unite the rays, which, proceeding from a point, fall upon them into another point. But the truth is, I spoke rather with regard to what they should do than what they really do. You seem, said the Marchioness, to have represented these glasses in the same light as tragic writers do their heroes; for these generally chuse to feign them what they ought to be, rather than imitate their characters such as they really are.

It must be confessed, Madam, that I used a sort of poetic licence in telling you convex-glasses united the rays in-

to a point, for it is not so truly a point as a little circle. This circle, which is called the *aberration* of the light, proceeds from two causes, the figure commonly given to the lens, and that disposition which the rays of light have to separate themselves when they are refracted. But indeed the figure of the lens is but a very small obstacle when compared to that of the different refrangibility. All attempts therefor to render telescopes more perfect by giving a new figure to the lens, so as to make it unite the rays truly in a point, would be in vain.

In the golden age, of which the poets give us so many fine descriptions, when the rivers flowed with milk, and the oaks distilled the fragrant treasure of the bee, when the rams appeared in the meadows arrayed in native purple, and the lamb displayed its vivid scarlet to the sun, before the hand of art had taught the fleeces to imitate different dyes: in these happy times, it is probable, the telescope would have given a more distinct view of the objects of nature herself painted in their genuine and beautiful colours, when the heart of man, animated with purer passions, appeared without disguise, and love had not yet learned to sigh by custom or art, nor ever wept for any motive but joy. But in our iron age, in which both the passions and colours have degenerated from their original purity, whatever be the figure of the lens, the point where the blue or green rays unite, will always be different from that of the yellow and red; there must always be an aberration of the light; and that little circle will never become a point. This is a circumstance very inconvenient for astronomers, whose affairs require that every thing should be seen extremely distinct; but this circle where the rays unite instead of the point where they ought to unite,

or the different refrangibility, which is the cause of their uniting thus irregularly, is a great obstacle to the obtaining the exactness which astronomers desire.

These accurate gentlemen, said she, must have patience and pray for the return of the golden age. In the meantime they must limit their desires and wants as other reasonable men do, and be contented with the different refrangibility of the rays, instead of that very great distinctness in objects which they desire. It is not possible to have all things at one time in this world. Is the knowledge of so many fine and surprising properties of light so very small an acquirement, that they cannot be satisfied without something more? Their desires and their wants however are so reasonable, said I, and have so great a connexion with those of other people, that Sir Isaac Newton has thought upon a method of satisfying them. With his own hand he ground glasses for telescopes of a new figure, in order to correct the deficiency of ordinary lenses. Then was the time to have all, or hereafter hope for nothing.

While his mind was employed in this thought, a new scene of optics opened to his view. He discovered the different refrangibility of the rays, laid aside the work he had begun, and invented a new telescope, in which a polished mirror supplies the place of what in ordinary telescopes is called the object-glass, and which had the greatest share in the aberration of the light.

I myself have seen the first telescope of this sort, worked by those hands which had pointed to the planets their road in the vast desarts of a vacuum, and opened to geometry the immense career of infinity. This instrument is preserved in a city of England, where philosophy and politeness hold a mutual empire; with this are treasured up

those prisms which the first time differently refracted the rays of light in the hands of our great philosopher, separated its emeralds, hiacinths and rubies, and unfolded to human eyes the celestial riches of the lucid robe of day.

In the reflection from a mirror, the rays are not separated as they are in being refracted through a lens, consequently the objects may be much more distinctly seen.

It has been tried in Italy, for even among us truth and Sir Isaac Newton have their admirers, that if a distant object, the one half red and the other blue, be viewed with an ordinary telescope, this instrument must be considerably shortened to give a distinct sight of the blue half, and on the contrary must be lengthened to shew the red distinctly; whereas in Sir Isaac Newton's telescope they appear equally distinct with the same length.

This reflecting telescope has besides another advantage over the ordinary ones; for one of Sir Isaac's invention, one foot long, is equivalent to one of twelve in the common sort; and one of forty foot to a hundred. And this is another convenience to astronomers who find great difficulty in managing long telescopes.

It is well for us, replied the Marchioness, that these astronomers will be now contented, for it seemed before a pretty difficult matter to please them. How is it possible, answered I, for them not to be satisfied with Sir Isaac Newton, who seems in every thing to have studied their advantage?

His system of optics, besides procuring them a more convenient and perfect telescope, has vindicated the honour of astronomy from an aspersión, which seemed in some measure to disgrace it in the eyes of the world. You are not ignorant that the honour of this science among men

consists principally in its exact prediction of eclipses and events, no less observable to philosophical than to vulgar eyes. Thales of Miletus was revered among the Greeks like a god for having predicted the year in which an eclipse of the sun was to happen, that is, when the moon would be interposed betwixt us and the sun, and by that means deprive us of his light.

As astronomy successively became more perfect, what would have caused a temple to be erected to a Thales, would only disgrace a Halley, Cassini, or a Manfredi.

The observatory is required to shew the precise minute in which the eclipse will happen, and its exact quantity, or in other words, whether the moon will obscure the whole sun or only a part, and how much precisely the obscured part will be.

Not long since all the calculations of the most celebrated astronomers had predicted two total eclipses, whose principal merit consists in not being very common, and in introducing a sudden and unseasonable night. An event, which though foretold and expected, never fails to terrify that whimsical species of animals called men, that *azylum* of the strongest contradictions, nourished by long hopes, impetuous passions, the most evident truth and the most palpable error, capable of making attempts beyond the powers of his nature, and subject to fears which his reason contradicts.

All the philosophers got up very early on the days appointed for this spectacle, in order to prepare themselves for observation. They all waited in the midst of the eclipse to see the light of the sun entirely extinguished, and a most gloomy and profound night emerge from the splendor of a fine day. But the event was contrary to their

expectations. There remained round the moon a luminous ring which made some falsely take them for annular eclipses. When the sun is nearest to the earth, and the moon at the greatest possible distance, if there happens in these circumstances a central eclipse, as they call it, the moon cannot hide all the sun, but there remains all round its edge a luminous border resembling a ring. But astronomers gained nothing by this explication, which was of no signification in the present case, and the world was but ill satisfied with astronomy which is now believed an impostor. The one murmured and were discontented, while the other racked their brains to find the reason of this ring, which had the confidence to appear in spite of all their calculations.

Some laid the fault upon a luminous atmosphere which incompasses the sun, as our air does the earth, and became visible when the greater light was obscured; others accused the atmosphere of the moon, which, being illuminated at the time of the eclipse, appeared like a lucid ring. But unhappily for them the first was innocent, and the second seemed so doubtful, that it might appear rather a mark of their consternation, than an explication of the phenomenon.

I find myself greatly affected with concern, said the Marchioness, for these unfortunate astronomers, abandoned by heaven and earth, and in the utmost danger of losing their reputation. It is however the office of humanity to have compassion on the afflicted. They must have recourse, answered I, to the Newtonian oracles if they would silence the voice of calumny. These were the anchor of hope in the present calamitous state of affairs.

When the rays of light pass near the extremity of a bo-

dy, they bend and incline towards the body itself, and are thrown into its shadow. If the edge of a knife be placed in a ray of light in a dark chamber, the rays, which pass at some distance from it, appear to bend and approach nearer its back. Grimaldo was the first who observed this quality, which is called the *diffraction* or *inflection* of light, and our philosopher afterwards illustrated it with many new experiments; and though he did ~~not~~ a great deal, desired to do still more.

The solar rays, which pass near the edges of the moon, must bend and cast themselves into the shadow of the moon herself. Observers then, who in the time of an eclipse are immersed in this shadow, must receive these rays bent from the edges of the moon, and see a luminous ring round her, a sort of twilight, resembling that which we see in the evening, and sometimes in the morning, at the horizon. The only difference between our twilight and this ring is, that the first is occasioned by the refraction which the light suffers in coming from the celestial spaces into our air, and the second by the *diffraction* which it undergoes in passing near the moon: but both are composed of rays which do not seem destined by nature for that purpose.

To give a stronger confirmation that this is the true reason of this ring, there have been made several globes of artificial moons, which exposed to the sun and full moon, have shown upon earth the effects of that diffraction which had appeared so fatal to astronomy in heaven.

Astronomers, replied the Marchioness, have certainly great reason to be satisfied with Sir Isaac Newton and his *diffraction*, which has delivered them from such eminent danger. But I must confess myself to be yet thoroughly

discontented with it. Will you permit me to ask, why those rays, which pass at some distance from bodies, must be inflected and bent? The idea which this new property of light presents me with, is so very strange that I cannot conceive it. I find, answered I, you are more difficult to satisfy than the astronomers themselves. You desire to know the cause of this *diffraction*. Well, I will inform you, but you must promise not to draw back and frown when I tell you it is the attraction which bodies exercise upon light. The attraction! said the Marchioness, with an air of surprize. You say this either to laugh at my credulity, or punish my too presumptuous curiosity. What! do bodies attract the light as a loadstone does iron? What ill consequences would arise supposing it were so, answered I? or rather how great an advantage has the science of optics in particular gained from this attraction between light and bodies, as all natural philosophy in general has from the universal attraction of matter, of which that between bodies and light is a consequence?

Attraction is the key of all philosophy, the great spring that actuates the frame of nature; the universal and mysterious force discovered and calculated by Sir Isaac Newton, proposed to the examination of philosophers by the great lord Bacon, and obscurely sung by the British Homer.

The Marchioness recollected herself, and looked very attentively in my face to see whether I spoke in earnest. Do you tell me seriously, she replied, that all bodies are attracted? This is quite a new world to me where I am an utter stranger and foreigner. Do not be discouraged, said I, for this has happened to many professed philosophers who have exclaimed against this attraction, affirming, that to admit it is introducing into philosophy certain

occult qualities which the antients supposed in bodies, such as sympathy, antipathy and the like, whose numbers multiplied with the phænomena themselves, by the assistance of which, they in an instant explained, or rather perplexed every thing.

They farther add, that it is recalling those occult qualities from those colleges of Europe, where ignorance still affords them asylum, to introduce them into true philosophy, from whence they for the happiness of mankind had been banished by the authority of reason.

But all these objections signify nothing, for attraction is so far from being an *occult*, that it is an extremely evident quality of matter, on which clearly depends the explication of *diffraction*, refraction itself and innumerable other things. It is not a name without reality, invented to explain two or three appearances, but a general principle diffused through all nature, and extends from the smallest grain of sand to the greatest planet. The Peripatetics resembled those antients, who for every little river or tree, nay even for the fever or the cholic, created a new deity. But Sir Isaac Newton, when he affirms, that light in passing near the extremity of bodies is attracted by them, does not pretend by that to give a complete explication of *diffraction*; all he undertakes is only to point out that property of matter on which the explication of *diffraction* depends, but the cause of this property is to seek. This he commits to those philosophers who have superfluous time enough to throw away in search of a thing which appears above the reach of human faculties. In short, all that Sir Isaac Newton attempts is to establish facts, and the general properties of matter, and from these geometrically to deduce phænomena and effects; and this is the

order we have hitherto observed in our discourse upon light and colours.

This new property, replied the Marchioness, is of a nature which my thoughts cannot so easily come into. This is one of those historical facts of which it is impossible to get a perfect intelligence without entering into the cabinet. I understand, or think I understand, how the rays of light are differently refrangible. This, among many other things, is very intelligible. But that bodies should attract the light, and that at a certain distance too, and in general that every thing should be mutually attracted, seems to me very difficult to conceive.

Some remains of Cartesianism, answered I, which you are not yet entirely free from, deceives you in this point. Perhaps you have hitherto flattered yourself that refraction arises from some one of those causes which in treating upon the Cartesian system were rendered so familiar to you, and upon this account you think refraction more intelligible than *diffraction*. Sir Isaac Newton himself appears in some places to have indulged the prejudices of this sect. In order to speak the language then current in philosophy, he said, that attraction perhaps might be the impulse of a subtile matter proceeding from bodies. But in fact, after he had proved the heavens to be empty, and the celestial bodies mutually attracted in those vast spaces, what room did there remain for the impulse and subtile matter? He seems to resemble certain authors, who, to make their history agreeable to any particular nation, are sometimes obliged to intersperse it with fabulous episodes, and give it the air of a romance. Is it not a great reproach upon mankind, that even the truths of Sir Isaac Newton were

obliged to use some little artifice in order to meet with reception among them?

Is not this rather an artifice of yours, interrupted the Marchioness, to surprize me by a motive of honour, and in this manner make me believe that I have no better conception of the subtle matter than of attractions, or how bodies should be endowed with motion, for example, than with that which you rightly term a *mysterious* force?

Your illusion, answered I, proceeds from hence, that you are familiarized to one idea and not to the other. You every day see bodies move and mutually communicate their motion, but you have never seen them attract each other. You are surprized at attraction, while motion appears to have no difficulty. In this you differ from philosophers, who, like poets, for the solution of any difficult point are obliged to have recourse to the divinity for the explications both of motion and its communication.

A Portuguese accustomed to reverence spectacles upon the nose of the gravest persons, as a mark of the gravest dignity, would probably be surprized to see a Chinese mandarin let his nails grow to an enormous length for the very same reason. And the cause of his being surprized in one case and not in the other is, that a long habit has connected in his mind the two ideas of honour and spectacles which have nothing in common with each other, but has not connected those of honour and long nails. I shall at least deserve more compassion than the Portuguese, replied the Marchioness, because the surprize of seeing matter united to attraction instead of motion will, I believe, be common to all countries.

As universal and excusable as this surprize may be, I answered, it must however at last submit to reason. If you

had never seen bodies move, it would have been impossible for you to guess how motion would be joined with extension and mutual impenetrability, which would be all the qualities you would then have been acquainted with. It is observation which has made you admit this property in matter, and observation must make you allow attraction. We are as yet but children in this vast universe, and are very far from having a complete idea of matter; we are utterly unable to pronounce what properties are agreeable to it, and what are not. We see bodies in very near the same manner as a person who should receive his senses by little and little. It would certainly be great temerity in him to affirm that there cannot be a property in matter capable of moving the eye, and should assign as a reason for this assertion, that he had never been able to observe any such property.

This person would not act like the Cartesians who form a world and a man just as their own caprice directed them; he would grow more cautious in limiting the power of nature and pronouncing the qualities of bodies, in proportion as he should acquire new senses, which would every day furnish him with fresh discoveries of these things.

Philosophers may be said in some degree to acquire new senses, or rather those they before had become every day more refined, and are by that means in a capacity of perceiving what perhaps they had once no idea of. Hence it evidently follows, how very cautiously they ought to proceed in assigning the number of properties in matter. It signifies nothing to say that some are more intelligible than others, for to speak ingenuously, they are all equally mysterious to us.

Will you any longer make a difficulty, Madam, to ad-

mit attraction as a property of matter when it is proved so many ways, and principally by the heavenly phænomena, which give the most shining testimony to a thing that you yourself so evidently demonstrate the truth of? I assure you for my part I shall never look for any farther demonstration of it than what you afford.

But I, replied the Marchioness, shall not be so easily satisfied, for I have need of the daily attestation of all heaven itself to convince me of a thing which yet appears so strange and surprising. It is absolutely needful then, continued I, to give you a full conviction of it. And indeed it would be doing a great injury both to Sir Isaac Newton and yourself, to endeavour to make you believe a thing without giving you good reasons. I am sorry this system cannot be explained to you with all the force of those demonstrations and calculations which accompany it; without these you must certainly lose a great deal. I will have patience, said she, if I cannot see it in all that lustre in which it would appear to a mathematician, and will act like those virtuosi, who, when they cannot get a picture, content themselves with the copy of it. I flatter myself, you will render it as like the original as possible. It is at present too late, I replied, for this expedition. To-morrow we will ascend into heaven, and from thence bring attraction down in triumph to earth. Some astronomical facts and propositions in geometry, which you may safely believe upon the word of Sir Isaac Newton, shall serve for a hippogryph, or flying car, to transport us to the skies.

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D I A L O G U E VI.

Exposition of the NEWTONIAN universal principle of Attraction, and application of this principle to Optics.

C O N C L U S I O N.

THE next morning, the Marchioness no less impatient for attraction than she had been for all the rest, after a few short compliments, began. It is now time to mount our hippogryph, and give him the reins. He will not grow weary, answered I, for a little journey, if I can remember certain horrible numbers.

All the planets revolve at various distances round the sun, who is almost nine hundred thousand times bigger than the earth, and forms a centre of their motion, while he remains in the tranquillity of a majestic repose. Nearest the sun, at a distance however of thirty two millions of English miles, is the little world of Mercury; then follows the lucid orb of Venus fifty nine millions distant; then our Earth eighty one; Mars, at one hundred and twenty three; the enormous bulk of Jupiter four hundred and twenty four; and the vast and slow-moving Saturn, seven hundred and seventy seven millions of miles.

These all preserve this natural order in their motions, that those nearest the sun complete their revolution or orbit in a shorter time, and the most distant in a longer: thus Mercury finishes his revolution in eighty eight days, Venus in two hundred and twenty four and some hours,

the Earth, as you already know, in a year, Mars in about two years, Jupiter in almost twelve, and Saturn in about twenty nine years and a half.

There is so great a dependance and relation between the periodical revolutions of the planets and their distances from the sun, that if we know the distances of any two, of the Earth and Jupiter for instance, and the periodical time of one, suppose of the earth, by a certain rule we may find the periodical time of the other.

I should have a much clearer idea of your meaning, said the Marchioness, if I had first read Fontenelle's plurality of worlds to convince me of the motion and agility of the earth. As you are now so great a proficient in philosophy, I replied, you must seek the true demonstration of this motion in England.

There have been observed certain appearances in the stars which some imagined to be consequences of this motion; but others who examined them more strictly, have discovered these appearances to be contrary to the laws of such a motion. The motion of light which is a considerable time in coming from the stars to us must strangely vary their appearances, and ought to be considered in conjunction with the earth's motion round the sun, in order to give a right decision of the question.

The sagacity of the English philosophers has in fact united these two motions, and by this means they explain these surprising and various appearances which in any other system are absolutely inexplicable. And thus we have attained to the certainty of a thing proved a thousand ways, but never strictly demonstrated by any.

The five planets, in whose number we may safely replace our earth, are called *primary*, to distinguish them from

other subaltern planets which revolve round a primary, as the moon does round our earth, the four satellites of Jupiter round that planet, and five round Saturn; and these subalterns are called *secondaries*. These last agree with their primaries in observing this order, that the nearest complete their orbit in a less, and the most distant in a greater time; and they keep this law with the same exactness and the same relation as their primaries do.

Another law in which the primary and secondary planets agree is, that they do not describe equal parts of orbits in equal times, but such parts of orbits as to make their areas equal. That you may better understand this other law of their motion, you are to suppose that the orbit of a primary planet is very near a circle which the sun is not placed directly in the centre of, but a little on one side. Imagine a line to be drawn from that point of the orbit where the planet now is, to the sun, and another line to be drawn from that point where the planet will be twenty four hours hence. The space contained betwixt the two lines drawn to the sun, and that part of the orbit which the planet has described in twenty four hours, is called the Area, and will be equal to such another area that the planet will describe in twenty four hours more; and thus in equal times the areas will be always equal.

The areas then, as astronomers express it, are *proportional to the times*. Thus, if instead of twenty four hours we put twelve, which is one half, an area described in those twelve hours will be only one half of the area described in the 24; and so, if we take a third or fourth part, will be the third or fourth of those described in the first time; and if that time be doubled, the area described in it will be doubled likewise, and so on. This law which the primary

planets observe with regard to the sun, the secondary planets observe with regard to the primary, round which they revolve; and this primary is the same to its satellites as the sun is to the planets of the first order.

I am extremely pleased, said the Marchioness, with the agreement between these two sorts of planets. I regard the sun as monarch of the immense planetary realm, in which the primary planets are the grandees and nobles; some of these possess certain districts where they exercise the same jurisdiction in little which their sovereign does in great, but all shew their dependance by revolving round him alone.

Our Earth is in possession of a little province, where she exacts obedience from the moon; and though she cannot vie with Jupiter or Saturn who have a great number of dependants, she is certainly superior to Mars, Mercury and Venus, who have none.

Your similitude, answered I, would be juster in the Cartesian system of vortices where these jurisdictions seem very well established; and it would be the more so, because, this philosophical poetry is fond of embellishing itself with comparisons and similes, and sometimes makes them even serve for reasons. But the two laws I have mentioned to you, will not suffer it. Indeed it is pity we are obliged to abandon these vortices, that present the mind with so clear, so natural and simple an idea. The planets, say the Cartesians, revolve round the sun, because a certain fluid in which they are immersed turns round too, and carries them with it like little skiffs forced along by the current of a river. The secondary planets revolve round their primaries for the same reason.

Nothing seems to be more evident than this. But the

misfortune is that these planets are not contented with barely turning round, but will do it by certain inviolable laws that entirely destroy all these imaginary systems.

Either these two laws cannot agree with the vortices, or agree so ill, notwithstanding all the efforts to that purpose, that one of their most illustrious defenders confesses, after all he has done in their support, he doubted whether those who refuse to admit them would not be confirmed in their opinion by the very manner in which he has endeavoured to defeat it. Besides these vortices are pressed by so many other insuperable difficulties, that heaven itself seems to have conspired in the destruction of this fine poem.

Far be it from us, replied the Marchioness, to oppose the decrees of heaven. On the other hand, I cannot reconcile myself to the idea of a poem in philosophy. What is this philosophical poetry to which I cannot assign a place in my thoughts? It ought to content itself with influencing the passions of men, but it has nothing to do with the single passion of philosophers, which is truth.

The Newtonian principles, answered I, have inspired you with very rigid sentiments. But this poetry, that thinks itself too much limited in the vast field of human passions, shall give you no farther trouble. Comets, the most declared enemies in all heaven to their vortices, will I believe be sufficient to overthrow it, for they seem to be made expressly for the destruction of systems.

It has been established, by virtue of I know not what, but however the philosophers have very readily believed, that the matter of the heavens was incorruptible, and that every thing flourished in a perpetual youth, insusceptible of the changes and vicissitudes which happen here below.

The comets appear at last almost naked, but in their approach to the sun are clothed with a formidable tail, of which they gradually divest themselves as they recede from him, and so return back naked as they came. And in this manner is the system of the incorruptibility of the heavenly regions, in great danger of being overthrown by these impertinent comets. And this perhaps is the reason why they were degraded from their celestial seat as worthless meteors formed by the vapours and exhalations of our lower world. But they would not remain long there; for besides many ancient philosophers who considered them not as one of the transient, but durable works of nature, the astronomers who must have their share in a thing above us, assure us, that they are very distant from the earth, and some of them farther off than the sun himself. These comets, said the Marchioness, are very bad omens to systems, if not to crowned heads. These were not all the troubles, said I, which they gave philosophers. When they were placed among the celestial bodies, they could not agree with that solidity which had been granted to the heavens upon the word of Aristotle; in order therefore to abide their demolishing and breaking to pieces the whole universe in their passage through these Aristotelian heavens, it was necessary to resolve upon making these last fluid.

When the heavens were thus made fluid, they became vortices, against which these factious comets renewed their enmity with more violence than ever, to destroy an agreeable imagination received by the world with so much applause, and which was defective in nothing but truth.

Some comets have made no difficulty to cross the orbits of all the planets, proceeding almost directly from the superior part of the vortex to the sun; others have moved in

a course absolutely contrary to that of the planets, without meeting, either in the first or second case, any resistance in their motion, which must necessarily have happened, if there was a certain matter that whirled round the sun, and this at several distances from him with the same rapidity as the planets supposed to swim in those vortices. Their motion would have been so weakened, that turning round the same way as the planets do, they would soon have yielded to the irresistible force of the vortices, not unlike the unfortunate barks, which, guided by an unskilful pilot or a malignant star, are ship-wrecked in the horrible cataracts of the Chinese rivers, notwithstanding all the struggling they can make to the contrary.

In short, these comets have in every instance acted directly opposite to the laws of vortices. So that to rescue them from the continual injuries they receive from these implacable enemies which lay hold on every occasion to commit all sort of hostility and impertinence, I see no other remedy than to destroy and banish these unhappy fluids for ever from the system of the world.

Your expedient, replied the Marchioness, is no less violent than that sometimes used in war, when one party destroys and ruin a country which they cannot defend against the enemy. And thus they make the same sacrifice to their weakness as you do to truth. This is a sacrifice at which I cannot be displeased, especially as it puts me into a better capacity of listening with more tranquillity to the new principle upon which the celestial system is built.

Sir Isaac Newton, continued I, founded his scheme in geometry, which we may call his native country. He began with demonstrating, that if a body in motion is attracted towards a point either moveable or immoveable, it

will describe about this point equal areas in equal times, and in general, that the areas will be proportional to the times; and on the contrary, if a body describes round a moveable or immoveable point areas proportional to the times, it will be attracted towards that point, that is, the body will have such a tendency towards the point, that if every other motion which impells it a different way should cease, the body would directly unite itself to that point, just as bodies here below, when left to themselves, fall directly upon the earth.

This principle, interrupted the Marchioness, is equally applicable both to the primary and secondary planets. Each of these describe areas proportional to the times, round the point about which they turn, if the sun, our earth, and Jupiter, may be termed points. The primary planets then are attracted by the sun, and the secondary by their respective primaries about which they revolve. Is not this a necessary consequence? It is without dispute absolutely necessary, answered I. But remember, Madam, this is a deduction of your own. The punishment is just, since you have made so much difficulty to admit the principle of attraction.

You say then that there is a force in the sun which attracts the planets to him, and after the same manner, a force in the planets that attracts the satellities; and this attractive force joined with another by which they all move from west to east, is the reason why the first revolve round the sun, and the others round their primaries, in a certain order.

The antients, in order to explain this difficult phenomena, built solid heavens, and created intelligences to put them in motion; on the other hand, Des Cartes had em-

barrasted the whole universe with the great and magnificent apparatus of his vortices. But after all, the motion of the heavenly bodies is by Sir Isaac Newton reduced to the most simple yet the most noble phenomenon in the world, which has been rendered much more familiar in Europe, than is agreeable to some persons. In short it is no more than that of a bullet, which would of itself proceed in a direct line, if the attractive force of the earth did not oblige it to move in a curve. The bullet very soon falls to the earth, because the greatest force we can possibly give it, is but little when compared to the vast extent of this globe. If it were possible for human weakness to throw one from hence beyond Peru, it is demonstrated that we should acquire a new satellite; it would like the moon revolve about our earth, only its motion being necessarily very soon weakened from the continual resistance of the air, while the gravitating force would lose nothing of its strength, this new moon would at last fall and destroy every thing it lighted on, after we had heard it make a horrible hissing over our heads.

All this you explain in two sentences; an evident proof of the significancy of a lady's words. What you have said is certainly a great deal, but not all. It still remains to know by what law this attractive force acts, that is, whether it be the same at all distances from the sun, or whether it grows weaker in proportion as the distance is greater. I will resolve you this question, the Marchioness replied, when you have furnished me with as many hints for that purpose as you did when I told you that the planets are attracted by the sun; and I hope you will afterwards make as genteel a commentary upon me as you did in the other case.

That law, answered I, of describing areas proportional to the times observed by every particular planet, furnished Sir Isaac Newton with means to discover the attractive force of the sun; and that other law which they observe, of describing their orbits in a greater time in proportion as they are at a greater distance from the sun, and that with a certain relation between these times and their distances, helped him to find out that the attractive force diminishes as the distance from the sun increases.

The attractive force diminishes with this proportion, that it is always so much less as the square of the number which expresses the distance from the sun is greater. In order to understand this cyphering, which perhaps at first sight may appear very formidable, it is necessary to acquaint you that the square of any number is nothing but that same number multiplied by itself; as four for instance is the square of two, because twice two makes four, that is, two multiplied by itself gives four.

I may now safely venture to propose you a problem, that as you have lately explained the phænomena of natural philosophy, you may now undertake the solution of mathematical problems: after this I do not see what you can do better than to shew some sort of gratitude, and discover the truth to him who has conducted you into its most obscure and retired paths.

The problem I shall propose to you is this: suppose the earth's distance from the sun to be one, and Jupiter's distance from him to be about five, considered with respect to that of the earth, the question is to know how much the sun's attractive force will be diminished at the distance of Jupiter?

Give me a little time to consider, answered she, with

some impatience, for the solution of a problem is no trifling affair. You have informed me that the attractive force is so much less, as the square of that number which expresses the distance is greater. The square of one which is the earth's distance from the sun, is one. And at the distance one, answered I, the force is supposed to be one, and the question you are to resolve is, how much that force will be diminished at the distance of Jupiter from the sun, which is five. The square of five, answered she, with great quickness, is twenty five. If the attractive force must be so much less as this square is greater, it follows that in Jupiter it is twenty five times less than in the earth. Is not this the solution of your problem? and may not I, like Archimedes, run crying about, *I have found it, I have found it?*

Yes certainly, answered I, but not in the same circumstance as he did, when his impatience was so great as to make him run precipitately out of the bath. The mathematicians ought rather to act as Pythagoras did upon the discovery of a certain truth, and sacrifice a hecatomb to solemnize this day which gives them liberty to embellish and brighten their gloomy catalogue by your name.

The law that the attractive force observes of growing weaker at various distances from the sun, is the very same to which all other qualities that flow from bodies, are subject; as smell, sound, heat, and which most nearly concerns us, light. Thus when you believe yourself to have solved only one problem, you have in reality solved two. Is then, replied she, the light of the sun as well as his attraction twenty five times less in Jupiter than with us? The very same number, answered I, serves equally for both. After the same manner you will find that the attraction

the light and heat of the sun, must be ninety times less in Saturn than with us. The twilight of our farthest Laplanders would be there the finest summer days, and in the most raging dog star of that planet, our seas hardened with perpetual ice, instead of swift sailing vessels, would groan under the weight of heavy chariots; whereas in Mercury, they would even in the depth of winter be dissipated into thin vapors, occasioned by this extreme proximity to the sun, and would thus leave their bottom dry, and present to pilots a horrid gulph, a dreadful view of the terrors of the deep; and to naturalists a beautiful scene that would furnish them materials to enrich their museums.

You see, answered she smiling, how many fine discoveries I have made without perceiving any thing of it. It is however true, that great affairs are generally brought to pass we know not how, and we are at last amazed to find them effected.

In human affairs, answered I, it is ascribed to their good fortune, if the Cæsars and Alexanders, after proposing only one end, acquire another which they never dreamed on. It often happens, that those very persons who are called fortunate, gain that name by some events very different from what they intended. The inventor of gunpowder, it is probable, proposed a quite different end to his studies than the discovery of a secret to destroy mankind with the greater facility; and that person who found a new world sought nothing but a more expeditious way to the richest part of the old.

On the other hand, in true natural philosophy and geometry, the Cæsars and Alexanders are more common. It is very seldom that we find only what we sought. The

discovery of one truth frequently produces many others which appear in spite, as it were, of those who seemed to disregard them. Any one who carefully seeks that law by which the attractive force ought to act at various distances, will at the same time discover that universal law by which all the qualities which flow from bodies are governed. Natural philosophy afterwards illustrates this general truth with peculiar experiments, and in some measure translates the obtruse hieroglyphics of the learned tongue into vulgar language. That decrease of the attractive force which immediately concerns light, is demonstrated by a very easy experiment, which we may try this evening, if you are not already sufficiently tired with philosophy and experiments.

Suppose one single candle to be placed in a room, and recede from it at such a distance as not to be able to distinguish the characters of a book, or a letter, unless perhaps it were a billetdoux, which may be read at any distance.

Place yourself afterwards at a distance twice as far from the candle as you were at first. In this situation the force of the light must be, according to the established law, four times less than it was at the first distance. The letter then cannot be read with the same distinctness as it was at first, unless the light be *quadrupled*: that is, the law requires that in the proportion as the light grows weaker, the square of the distance must increase. And this proves the experiment to be true; for the letter at the second distance is then only read with the same distinctness as at the first, when three more candles are added to the single one, or, in other words, when the light is *quadrupled*.

Considering how very easy people are apt to forget

these objects in their absence which made the greatest impressions upon their mind when present, I cannot help thinking, said the Marchioness, that this proportion in the squares of the distances of places, or rather of times, is observed even in love. Thus after eight days absence, love becomes sixty four times less than it was the first day, and according to this proportion it must soon be entirely obliterated: I fancy there will be found, especially in the present age, very few experiments to the contrary. I believe, said I, that both sexes are included in this theorem, which seems rather to follow the cubes of the times, which is certainly more convenient, and requires only four days for an intire oblivion. But, in genneral, I believe we may without scruple establish the proportion of the squares, for eight days are common enough to cure the most vehement passion. You alone have power to reverse this theorem, and make the remembrance of you, and with that a desire of seeing you, instead of diminishing, increase according to the squares, or rather the cubes of the times. No! no! said the Marchioness, gallantry must never destroy a theorem. I am willing to enter into the general rule, and shall think myself exceedingly happy if I have been able to establish any thing fixed and constant, in an affair so inconsistent and wavering as love. If geometry, answered I, was permitted to get some footing there, it would in a little time produce wonders. The conclusions would be the most ready and elegant imaginable.

But to be serious, said she: our conclusion in natural philosophy was, that the attractive force of the sun diminishes in proportion as the squares of the distances increase. I suppose the attractive force of the planets will follow the same proportion with regard to their satellites. The sa-

tellites, answered I, which turn about any planet, observe the same relation between the distances and the times of their revolutions, as the planets themselves do that turn about the sun. This is evident in Jupiter and Saturn, who have more than one satellite, and consequently the law of their attractive force will be the same as that of the sun.

In the earth, who has only a single satellite to her share, this is not altogether so evident. But what reason is there why it should not be the same in one as in the other?

If we had another satellite revolving about our earth at a distance different from that of the moon, it would discover whether the attractive force of the earth observes the same law as that of the sun, Jupiter and Saturn. This defect however is supplied by the bodies which we see every day fall upon the surface of the earth; for we are to believe that the force which would make the moon fall if she lost her motion from west to east, is the very same that makes bodies here below fall upon the surface of the earth when they are left to themselves: for since it is demonstrated that the earth has an attractive force, it is evident we must in this force seek the cause of gravity, another phenomenon, which the vortices have been as unsuccessful in the explication of, as in that of the planetary motions.

If we could raise bodies from the earth to very considerable distances, compared with that at which we stand from the centre which is very great, we should see the force of gravity prodigiously diminished in them. A man of war of a hundred guns, for whose formation a whole forest was cut down, and a whole mine exhausted, would be overset by the slightest breeze of a zephyr. The famous *Stone-henge* upon Salisbury plain, the fruit-

ful source of fables both to the learned and ignorant, those Colossian heaps which are held together by the force of gravity, would be no more than houses built of card. The velocity in the fall of heavy bodies would be considerably retarded. Bombs, those artificial thunders, would not be more terrible than so many flakes of snow. But these experiments are impracticable; one of the greatest distances we can attain is *Pike Teneriff*, which is only about three miles perpendicularly high. Besides the air would be too thin for respiration, and the cold, which must be exceedingly sharp at a greater height, would render any experiment fatal to the philosopher who had the courage to undertake it.

Nature, replied the Marchioness, has in this case denied us the means of being complete Newtonians. She has here confined us within the bounds of probability. If the attractive force observes a certain law in the sun, Jupiter and Saturn, why should not the same force observe it here on our earth? In this point, answered I, we have no reason to complain; we have no need of higher mountains, and a different constitution of air, in the present case. All these things, and the defect of another moon, are, as I before observed, supplied by the bodies which fall upon the surface of the earth. We may compare these bodies to the moon herself; and thus instead of probability we shall have evidence, and be even in this point good Newtonians.

It has been deduced from observation, that if the moon should lose her motion, and fall towards the earth, that force which would set her a falling would be three thousand six hundred times less than the force which makes bodies fall upon the surface of the earth. You see how

*Balloons were then in known
we reach 7 miles and have*

well this agrees with our principle. The moon is distant from the centre of the earth, where the attractive force chiefly resides, sixty times as far as these bodies: the square of sixty is 3600: the attraction then of the earth to the moon is diminished in the same proportion as the square of the distance is increased; and this is exactly agreeable to the established law in Jupiter, Saturn, and the Sun.

If the moon should happen to fall upon the earth, replied the Marchioness, it would present a fine and agreeable sight to the Newtonians: they would certainly have neither curiosity, eyes, nor calculations for any thing else. This might very easily happen, answered I, if every thing was body, as the Cartesians affirm; and those ancient Gauls, who were apprehensive the heavens might one day or other fall upon their heads, would have some reason to fear it in the system of their own Des Cartes: for it has been demonstrated that if this planet was to move in a place absolutely filled with matter, without the least empty space, let this matter be supposed ever so subtle, fluid and æthereal, her motion from west to east would be so retarded that it would soon grow weaker, and at length totally fail. And thus yielding to the force of gravity, she would fall precipitately from heaven to earth, and we should no more behold her that triform goddess we before admired, but a stranger banished from the most shining of her three kingdoms, and no longer the ornament of heaven amidst the friendly silence of the night.

The other planets would undergo the same fate if they moved in a plenum. These would all, some sooner and others latter, fall into the sun, and supply that immense volcano with a greater quantity of matter. He would then reign the sovereign of a depopulated empire: his ani-

mating light would shine in vain: Not a single planet would be left to partake his pleasing influence, nor receive from him the seasons and the day; for both the comets and we with our moon should be stifled in him, if we met with an obstacle in our æthereal road. This would be a new punishment to an age fruitful of crimes, in the system of that English writer * who makes the glorious body of the sun the mansion of grief, and the seat of eternal despair.

I assure you, for my part, I should be one of the first, continued I, who would run to see the moon fall upon the earth. What an agreeable spectacle would it be to see, in proportion as she approached to us, that face, that mouth and nose, which we discover in her rather by our imagination than our eyes, gradually transformed into great mountains, vallies, plains and the like, which must certainly fill the vulgar with great astonishment: nay even philosophers themselves, who can never sufficiently master those two great enemies of reason, fancy and prejudice, could not help looking on this phenomenon, without some degree of surprise. As she approached still nearer, said the Marchioness, should not we descry the sighs of lovers, dedications to princes, courtiers promises, vials filled with the judgment of our fages, and all the other lost things which Ariosto places there? You have not read the Plurality of worlds, answered I, and therefor are not capable of seeing the greatest curiosities in that planet; since you are not yet acquainted with the force of a *why not*, which peoples the whole universe.

But one thing which I should take great pleasure in observing, if the moon should really hapen to fall, is,

* Mr. Swinden in his treatise of the nature and place of hell.

what treatment the earth would give the moon in going to receive her.

What! replied the Marchioness; is it a point of ceremony established among the planets, that if a satellite should fall upon its primary, the latter must go meet it, and shorten its way? This ceremony, answered I, is founded upon mutual and reciprocal attraction. If the earth attracts the moon, why should not the moon attract the earth? The attraction which the earth exercises upon the moon, is lodged in that matter of which the earth is composed; why then should not the matter of which the moon is composed exercise its attractive force upon the earth, since all matter is entirely the same, and only differently modified in different bodies? Besides *action*, as the philosophers express it, *is always equal to reaction*. You cannot press this table with your finger, but it will be equally re-pressed by the table. Thus if two little gondolas made of cork, in one of which is placed a loadstone, and in the other a piece of iron, are set a floating upon the water near each other, the loadstone will run as fast towards the iron as the iron does towards the loadstone; and if either of them be hindered, that left at liberty will spring towards the other, which could not happen unless the iron attracted the loadstone as much as the loadstone itself does the iron, or, in short unless the attraction were reciprocal.

I perceive, said the Marchioness, what will be the conclusion of all this. The sun attracts the planets, and consequently the planets attract the sun: the secondaries attract each other, and are all attracted by the sun, and all attract him. Does not this multiplicity, this chaos of attractions, perplex not only me but the system itself too? No,

Madam, answered I, it happens in this just as in the new geometry, of which I was speaking to you the other day, in which all these innumerable orders of infinitely small quantities, instead of perplexing, render it more subtle and perfect.

This mutual attraction, diffused through the universe and all its parts, retains the wandering planets in their orbits, and connects all bodies, the earth, and us ourselves, by strong though invisible ties, and regulates and tempers every motion in such a manner, that its existence and irresistible laws are every instant apparent.

In thinking on this reciprocal attraction, said the Marchioness, something comes into my mind, which I dare not however propose as an objection to a system which the philosophers themselves cannot venture to oppose. It appears to me that if there really was such mutual attraction, we must see the effects of it in those bodies which surround us, if not every instant, at least very often, just as we discover from their gravity the effects of that general attraction which the earth exercises upon them.

When any little, light, body, as a feather for instance, is placed near a palace, a hill, or any thing whose attraction is very strong, why do not we see it presently obey the force which attracts it, and move, as it should do, towards the palace or hill? When our mind is possessed by a very strong passion, answered I, what is the reason we do not feel the weaker, unless it be that the strong passion attracts the whole soul, so as not to suffer the weaker to make any impression upon it, and thus we become insensible to all the rest which are not in themselves either light or weak.

The furious passion of Phædra for Hippolytus in Racine,

does not permit her to feel that strongest passion in the fair sex, the desire of beauty. Her ornaments and her whole dress are in that disorder which perhaps neither the absence nor death of her Theseus could ever have produced in them.

I comprehend you, replied the Marchioness, notwithstanding your parabolical method of explaining this point. The very great attraction which bodies feel from the earth, if I may use that expression, renders them insensible to that of the other bodies which surround them. Bodies, answered I, attract only in proportion to the quantity of matter they contain. I make no scruple of using mathematical terms to you, for to use any other would be an affront to a person who has given the solution of a problem.

Thus a ball of gold, besides many other advantages, has a greater attractive power than that of wood, because it has a greater weight; and if the first be a hundred times heavier than the last, that is, if it contains a hundred times greater quantity of matter, it will have its attractive power a hundred times stronger.

Now the attraction of this great ball upon which we stand is diffused on all sides, and draws every thing to it with an immense force, and by that means hinders us from perceiving the effects of that particular force, which the little balls by which we are surrounded exercise upon each other.

A globe of the same density with the earth, and of a foot diameter, attracts any little body placed near its superficies, twenty million times less than the earth does. The attraction of the highest mountains, as that of Pike Teneriff, Ararat, or even the Apennine, notwithstanding

the pompous description made of it, is absolutely imperceptible.

But it is not so with the effects of the lunar attraction upon this vast collection of waters that some philosopher made the first principle of things, which by the easy method of navigation joins the most distant countries, and transports to us from another world those balms and aromatics which season the European entertainments. You seem, replied the Marchioness, to have a very lively sense of our obligations to the ocean, and the advantages we receive from it. But has not the philosopher amidst these entertainments forgot the attraction of the moon? The ocean, answered I, every day shews us the effects of this attraction, which extend its empire throughout all nature. The ebbing and flowing of the sea, a phenomenon, which in the most polished age of Greece, Alexander the Great took as a mark of the divine displeasure, and with which the Romans in the golden age of Julius Cæsar were but very little acquainted, is only a consequence of that attraction the moon exercises upon the fluid and yielding part of our globe. Chapelle in his celebrated voyage, that model of polite and agreeable wit, believed that no one but a water-god could penetrate into its cause.

This god relates to him, that when Neptune was made governor of the sea, the rivers went to congratulate him. The Garonne upon this occasion retained something of the haughty temper of his country, and his compliments were not so submissive as was necessary in addressing that power who raises the tempest by a single nod, and with an *I will*——— silences them to a profound calm.

The punishment which this arrogant river received for his crime, was to be repelled twice a day back to his source.

All the rivers which flow twice a day into the ocean undergo the same fate. But why, answered the Marchioness, should the other rivers who were not guilty of this gascon behaviour suffer the same punishment as the Garonne? If it was permitted to make objections to superior powers, I would humbly propose this to Chapelle's Neptune.

You may make objections equally strong, answered I, to all the human systems that have been made to explain this phenomenon. Some affirmed the respiration of this vast animal the earth and the sea to be the reason of it; others a great gulph in the northern ocean near Norway, which emits a vast quantity of water and afterwards swallows it up again, a most fatal circumstance both for the fishes and philosophy which have the misfortune to be plunged in its deeps. The ancient Chinese, who supposed their little country of four leagues extent, to be the universe itself, asserted that two great nations, descended from a certain princess, the one inhabiting the mountains, and the other the sea-shore, had frequent wars with each other, and this was the reason of the flux and reflux according as either of the combatants was drove back towards the mountains or the sea.

Such perhaps was the infancy of philosophy among all, even the most sagacious people. The explication of Des Cartes which was produced in a later age of the world is ingenious enough to render it agreeable, but not accurate enough to be true. The same English philosopher who cast an impenetrable obscurity over vision, by involving it in his contractile and expansive forces, has endeavoured to involve this phenomenon also in the same unintelligible terms. This gloomy fancy diffused itself like an universal

contagion over the whole face of things, and infected the whole system of natural philosophy.

According to this opinion, the most simple and evident method of explaining the tides, is by ascribing their cause to the contractive forces of the earth and moon, by which the one raises and the other depresses the water. To these he unites the expansive force of the sun, which, though always contrary to the contractive, yet upon this occasion must act in concert with that of the moon. These unintelligible terms, which have not so much as the fashion to support them, can imply nothing in the author but a vehement and vain desire of giving his name to a new system of errors. These philosophers, said she, appear to me the priests of Chapelle's divinity: their explications at once discover both the temerity and weakness of their philosophy. Our's, answered I, takes delight in difficulties, and comes off in triumph; amidst the thorns we are sure at least to meet with roses.

That portion of the water immediately under the moon and nearest to her, must be more strongly attracted than the rest which she looks obliquely on, and which is at the greatest distance from her. The ocean then must flow together from all parts, and be heaped into a mountain of waters whose summit will be under the moon herself.

The earth itself is a little attracted by the moon, but that part of the water which is directly opposite to the part under the moon is least attracted, because it is at the greatest distance.

This part then will be as it were forsaken by the ^{Sea} earth which a little follows the attraction of the moon, and will there form the summit of another watery mountain, and

thus there will be two, the one totally opposite to the other.

The ocean then must swell, and in some measure lengthen itself in that part where the moon is, and in the part opposite to her, and thus from the figure of an apple be changed to that of a lemon, whose extremities will always follow the moon in her diurnal course; so that the water will be at one time depressed, and at another raised, both in the same place.

In every part of the ocean there will be two tides, during the time which the moon employs in returning to the same point of the heavens. When she is at the meridian, the waters must be raised, and when she sets, depressed; another elevation when she is at the meridian of the Antipodes, and another depression when she rises.

All this must unavoidably happen if the whole earth was covered with deep waters, and they immediately obeyed the attractive force of the moon. But because there is some time necessary for the accumulating the waters, and their course is interrupted by shores, straights, islands, and the like, there are some irregularities in the tides.

These irregularities however are not so great, but twice in every twenty five hours, which is nearly the time that the moon employs in her return to the meridian, we see the vessels laden with the riches of the universe go up with the tide along the silver waves of the Thames, and twice descend with the reflux to go in quest of new treasures. And this advantage, which in the system of Chappelle was inflicted as a punishment, all the rivers which flow into the ocean enjoy.

Have our Mediterranean rivers, said the Marchioness, ever offended the moon, that they are not suffered to en-

joy the same advantage? Perhaps they have affronted her as the Garonne did Neptune.

The straight, answered I, by which the Mediterranean has a communication with the ocean, is too narrow for so great a sea, and is disadvantageously situated, since it looks towards the west, to receive the great flood of the ocean that follows the moon from east to west.

On the other hand, the tide which is formed in the Mediterranean itself is too much interrupted with islands, shores and straights, for the flux and reflux to be very considerable. In the Adriatic, on the contrary, it is more sensible than in any other place, because the sea is very narrow, just as the motion of a river is most apparent and seems most rapid when confined between the arches of a bridge. In our fine city founded by the gods upon the ocean, the vicissitudes of the flux and reflux carry the fluctuating gondolas from one side to another, while the gondolier sits at his ease, and singing to the agreeable light of the moon, teaches the sea nymphs the flight of Erminia, or Rinaldo's love.

The changes of the tides are still less perceptible in the Baltic sea, the Mediterranean of the north; for this sea bordering upon the frozen regions of the Pole, and very distant from the course of the moon, seems more adapted to ice and rocks than to warmth and attraction.

In the shores of the southern and oriental oceans, to Japan and China, the tide is very considerable by reason of the extent of the seas; and in our ocean its effects are incredibly prodigious. There are coasts near Dunkirk, where the sea draws back for the space of several miles, and afterwards on a sudden returns and overflows the same space again, alternately covering and disclosing those sands so

very suspicious to sailors, not without sometimes disturbing the ladies in that country, who venture to walk upon the margin of the sea, whose very shores are faithless and deceitful. These are a sort of natural sea fights, where at some parts in the day two armies may engage on dry land, and at others, two fleets, at least such as those of the ancients were.

In some rivers the tide rises to more than fifty foot high, especially if the sun and moon act in conjunction to render the flood considerable.

Though the moon may be regarded as the empress of the ocean, the sun however has his share in it. Notwithstanding he is at a greater distance from the earth than the moon is, yet in return he is so much greater, that it is not proper he should remain idle, but lend his part to the production of the tides. The rest of the heavenly bodies have no sensible influence in this case, the vast distance they are separated from us renders them too small.

When the moon is in her quadratures, the tides are less than at any other times in the month. The reason of this is, because the attractive forces of the sun and moon crossing each other, are as contrary as is possible to the swelling of the sea in the same situation.

On the other hand, when the moon is new or full, she is in the same direct line with the sun in respect to the earth, their forces are united, and then the tides are highest.

It is to be observed however, that the motion begun in the waters, and retained for some time within them, must be some days after the new or full moon, before it produces the greatest raising of the sea. So in summer, the heat of mid-day that remains in the air, being added to the following heat, less intense in itself, is the reason why

we have not so great need of the assistance of the fan to supply us with fresh air at noon itself, as we have some hours after.

The greatest of all the tides happens at the new or full moon of the equinoxes; for besides the conjunction of the solar and lunar force, the waters in this case acquire a greater agitation; but because the sun, notwithstanding our freezing, is nearer to the earth in winter than in summer, these great tides do not happen at the precise time of the equinoxes, but a little before the vernal, and something later than the autumnal, that is, in the month of February and October.

In Mercury, Venus, and Mars, the tides are governed by the sun alone, though they must be almost insensible in Mars, because that planet is at so great a distance from him. In Jupiter and Saturn, the distance from the sun is so very great, that he can have absolutely no influence over the tides. They will confound each other according to the caprice of the satellites, the great number of which will render them very irregular.

If we knew the time of Saturn's rotation as we do that of Jupiter's, and were as well acquainted with the geography of both, and the quantity of matter contained in their moons, as we are with their distances and revolutions, we might conjecture the quantity and period of their tides, and send tables of them to their pilots. Thus are we again transported by attraction into heaven, to vast and remote worlds, where this powerful quality holds its most conspicuous and shining seat.

By the help of this, replied the Marchioness, we can travel thousands of miles in an instant, and are well recompensed by innumerable great and shining truths. A French

author, I answered, a zealous propagator of this system, like us transported by attraction to these distant worlds, thinks with great probability, that the moons of Jupiter and Saturn as well as ours had once been comets, which passing near enough to these planets, to remain confined within the sphere of their attraction, were constrained to revolve round them, and thus degraded from the rank of primary to that of secondary planets.

Saturn has obtained so advantageous a situation as to make him the most happy in the number of his conquests. For the same reason he was able to acquire a fine ring, that encompasses his body, and which was formerly the tail of a comet that unhappily passed too near him.

This Saturn, replied the Marchioness, must be very terrible to the comets that approach a little too close to him. He must be the same to them, as the *Cabo tormentofo*, to which avarice afterwards gave the name of Good Hope, was to the Portuguese. It must, I fancy, have been a very agreeable sight to see Saturn at once adorn and enrich himself with a splendid ring, while the poor comet was forced to pursue its journey, spoiled of the honour of its shining train.

He robbed it of nothing, answered I, but what it enjoyed at another's expence, according to the supposition of a certain French author, who assures us, that the comet, in crossing the atmosphere of the sun, had from thence stolen its tail. But the Newtonian opinion is, that the tails of comets are formed and composed of certain vapours arising from the comets themselves, when they are near the sun.

Is it not a very great advantage, replied the Marchioness, to be possessed of a system that supplies even the imagination with the most pleasing amusement, by those

strange and surprizing events which it renders possible? And all this, answered I, only by the force that among us makes a stone fall to the earth. This attraction, said she, appears to be the same in the hand of nature, as the subject of a composition in that of a skilful musician. Be it never so simple, yet when he undertakes it, he will diversify it a thousand ways, and make it appear every moment new; in short, he will find enough in it to form the most harmonious concert in the world.

Nature, continued I, wants no other subject at once to regulate and vary those innumerable and vast planetary systems, which probably revolve round the fixed stars, those luminous and attractive suns that cheer the night, and which we debase by giving them the names of our miserable heroes. But why should these heroes, said the Marchioness, remain unmoved and fixt? If they have a mutual attraction, how comes it to pass, that they do not approach each other and run all together? You have, perhaps, some other parable ready which only waited till I should propose a difficulty. No, Madam, answered I, unless you take it for a parable when I tell you that this would exactly happen, if the number of those suns was not infinite. Those which are upon the superficies of this immense sphere of suns would be united to those next them, because they would not have any thing to attract them a contrary way, and by that means keep them in their orbits. And thus these successively running into those next them, and these last into others, they would be all heaped together. By this means in a little time there would be in the whole universe only one sun of an enormous size.

But what is the number of these suns? What are the limits of their sphere? Is not the centre of it throughout,

and the circumference in no place? The difficulty you have moved would be alone sufficient to induce us to multiply the stars, *ad infinitum*, even if we had not a thousand reasons besides.

I am quite lost replied the Marchioness, in this infinity of suns, and planetary worlds; pray let us return to our own. We are possessed of a system capable of diversifying it to infinity, if we were so fond of infinity as to desire it. And a system, answered I, which predicts and gives a reason for the very smallest irregularities that can happen. After attraction and its laws were established, how sublime a geometry was requisite to find out what path the planets must keep in the spaces of heaven, and how much more sublime still to foresee exactly how much they would deviate from that path in the constitution of the present system? The vastness of the objects renders general rules difficult, and the niceness of the variations renders the exceptions still more difficult.

The sun who was esteemed immoveable in the centre of the system, and imagined himself exempt from any irregularity, is found however to be subject to it; for the attraction between bodies is always mutual, and every cause must have a correspondent effect proportioned to its activity. As the planets and sun reciprocally attract each other, he must be sensible of their force; so that to speak with the utmost rigour, he continually changes *his*, as they vary *their* situation with respect to him. After all our speculations then, replied the Marchioness, to prove the immoveability of the sun, we are at last reduced to make him move again. Had it not been better, continued she, with a certain malicious smile, to adhere to the common opinion without giving ourselves all this trouble?

Do not you act like those persons, who after employing their reason to divest themselves of popular prejudices, are afterwards obliged to have recourse to the same reason to resume them, if they have an inclination to live and converse with their fellow mortals?

Our case, answered I, is extremely different. The question then was to make the sun revolve about the earth with such a motion, as to run a million and a half of miles in one day. But at present the Earth herself continues to revolve about the sun, and he has no other employment than to approach or recede a little sometimes towards one and sometimes towards another side of the common center of the whole system. This motion is insensible in astronomy, and is in fact only a mathematical subtlety with which I thought myself obliged to make you acquainted. If the planets were all on one side, you are sensible that their united forces must act upon him with the greatest possible strength, in order to draw him back to themselves and make him recede from the center of the system: they would not however attract him, considering the enormity of his bulk, any more than one of his diameters. I am very willingly convinced of my error, said she. The sun, who, notwithstanding his vast size, is subject to the general force of gravity, may serve for an example to great kings, whom neither the extent of their fortune, nor the superiority of their station, can ever exempt from an observation of the universal laws of humanity.

Our moon, continued I, is at present subjected by attraction to the minutest and most exact calculations of astronomers. Her very irregularities, her caprices are reduced to certain and constant rules. Comets, those enemies to systems, who made still greater resistance to the power of

numbers than the moon herself, are at length obliged to revolve about the sun. And though their orbits are much more oblong than those of the planets, yet they observe exactly the same laws.

By observations made upon their appearances, philosophers have assigned what orbits the comets must run in this system, and these in fact are the orbits which they really have run, almost with the same exactness as the other planets. Notwithstanding the imperfect observations left us by the ancients concerning comets, the moderns have ventured to predict the return of some of them, in the same manner as they do eclipses. And indeed, what is there which this system might not authorise? A Titian could easily judge of a picture from a rough draught.

The prophecy of that ancient is now fully accomplished, who even in his time foresaw that posterity would calculate the periods and predict the returns of these bodies, these eternal monuments of the ignorance and weakness of human nature.

It is expected that the comet which appeared in 1658, will return twenty three years hence, and I hope we may flatter ourselves we shall observe it together, you still young, and I not very old. You shall be the Urania to give a right direction to my telescope. What a vicissitude of things, replied the Marchioness, is there in this system! I am metamorphosed into a Urania, and supposed to be young at a time when it becomes unpolite to talk about years, and the non-appearance of a comet rendered more fatal than its appearance! It will appear too soon, answered I, to put us in remembrance of our past time, and our attraction. In this case, replied she, we may express ourselves contrary to the common saying,

'Tis expectation makes a blessing dear.

It is at present indeed a great happiness to be an astronomer. They at least expect nothing in vain; and how great a pleasure do they owe to this system, which gives them a full power over every thing in that heaven which is the object of their projects and desires!

Nothing, answered I, was a greater curiosity to astronomers, or more glorious for the Newtonian system, than the conjunction of Jupiter and Saturn, which happened in the beginning of the present age, an age so fertile in the most surprizing events. These two great planets were to approach each other, which the vast extent of their orbits, and the time employed in describing those orbits, had not very often suffered them to do.

If it could ever be hoped to see the effects of this mutual attraction in the disturbance and alterations in the motions of the planets, it was upon this occasion, when the two most powerful, in the whole solar system, approached each other, at a distance however of three hundred and fifty millions of miles. This was an observation in *great*, as decisive for the Newtonian celestial system as the experiments of refracting the coloured rays with a second prism, in order to prove whether colour was a modification of light or no, was in *little*. The curiosity in this affair was so much the greater, because the Newtonian system was then in its infancy; and time which gives strength to truth, and in which error vanishes away, had not yet decided any thing to the world in its favour.

The disturbance which Jupiter, the greatest of all the planets, occasioned in the motions of Saturn, and that

which this planet reciprocally exercised upon the satellites of Jupiter, were so considerable that they could not escape the observations and testimony of astronomers, even those who were the least inclined to adopt the system, whom a difference of opinion from the wagers held against it, might easily induce to regard this phenomenon in a very superficial manner. And Sir Isaac Newton had the pleasure of extorting from his very enemies so strong and solemn a confirmation of his system. What are the triumphs of the Cæsars and Alexanders, those miserable conquerors who overturned two ~~parties~~^{parties} of this globe, when compared to the philosophical triumph of him who first discovered the vast extent of the universe?

Astronomy, said the Marchioness, has by this triumph amply rewarded Sir Isaac Newton for defending it so well in the affair of total eclipses. This mutual assistance, this commerce, if I may use the expression, of truth, must certainly be a very great honour to the sciences. This commerce, answered I, was never more evidently seen than in attraction. We may affirm, that every science, with a sort of emulation contributes to confirm this truth, just as the whole world anciently did to the raising the Roman empire.

Though I told you that the effects of attraction are more remarkable in the heavens than any where else, yet it is also very evident in all natural philosophy, hydrostatics, chemistry, and anatomy itself. Mr. Muscembrook, who even in philosophy ~~presents~~^{represents} the character of a true republican, confesses with that freedom that becomes a member of the Belgic state, that for the space of many years spent in the greatest variety of experiments, he has observed in all bodies certain motions and effects which could not be

explained or understood by means of the external pressure of any ambient fluid: but that nature proclaims aloud a law infused in bodies by which they are attracted, without a dependance upon impulsion. Chemical fermentations, the hardness of bodies, the round figure of drops of water, and of the earth itself, the separation of the juices in the human body, the suction of water by sponges, its ascent in those tubes which from their extreme smallness are called *capillary*, and a thousand other things, are incontestable arguments for this attraction. I believe that after so many repeated proofs you will permit me to introduce it triumphantly into optics, in order to explain the effects which depend on this mutual attraction of light and bodies. It would be very extraordinary, said she, if I should refuse to admit the mutual attraction of light and bodies, after I have seen the Sun and Saturn attract each other at so enormous a distance.

Not to say any thing more of diffraction, answered I, is not refraction an effect of this attractive power? Does it not arise from hence, that the mediums through which the light passes are indued with this force in a greater or less degree, according to the greater or less density of the medium? Otherwise the immense force of the earth which attracts every thing to herself, would render it impossible for any prism, if it were as big as pike *Tenerif*, to attract the smallest ray of light.

While the light passes through the same medium, because it is equally attracted on all sides, it will not decline to any, but move forward according to that direction it received from the sun or any other luminous body: if in its way it meets with another medium of a greater force, such as glass for example compared to air, must it not de-

cline towards this medium and immerse into it, approaching more or less to a perpendicular as the attraction of the new medium is more or less powerful?

In going out of glass into air, the light is again attracted by the air and the glass; but because the force of the glass is greater than that of the air, the light will remain behind the surface of the glass from whence it goes out, or behind that of the air into which it enters, and which immediately touches the glass itself.

Thus you see, how easily by the help of attraction is explained a phenomenon, which Des Cartes could not account for, unless by supposing that light could with greater facility pass through dense than rare mediums; which is in other words saying, that what makes the greatest resistance to all other bodies, must, by some other privilege of which I am ignorant, make the least resistance to this. It is surprising to see how all that experiments have discovered to happen in refractions, are geometrically deduced from this explication of the Newtonian philosophy.

To me, replied the Marchioness, who cannot enter into the sanctuary of the mathematics, it seems a sufficient proof that as the attractive force is greater in proportion as the density of the medium is so, the refraction must in that case be proportionably greater.

The Dutch, answered I, have found it to be much greater in Nova Zembla than here among us. The air is extremely cold, and consequently dense in this country, the habitation of white bears, and some Europeans, the miserable victims of the avarice or curiosity of their species.

By the help of this very great refraction they had the pleasure of seeing the sun after his long absence many days

before the science of cosmography had permitted him to appear, and the density of the air, which generally oppresses and damps the spirits, served in this retreat of misery and darkness, to revive their imagination by an unexpectedly early light.

We may at present hope for more exact observations upon the density of the air and the refractions of this climate, which have never yet been examined by philosophical eyes. A learned company is now setting sail from France, to the Bothnic gulph, and another to Peru, in order by their united observations to determine if possible the true figure of the earth, and animated by the love of science, have the resolution to change the gardens and the delightful seats of pleasure in their own country, for the frozen rocks and desarts of Lapland.

In North America, the colds are incomparably more sharp than in Europe, at the same distance from the pole. There are in those seas mountains of ice of the same date perhaps as the world, among which are sometimes found ships at full sail as motionless as upon dry land.

Doctor Halley, whom the English nation regards with the highest respect as the friend and companion of Sir Isaac Newton, and whose thoughts are employed on no objects that are little or trifling, believes that these countries were once perhaps nearer the pole than they at present are; that a comet by giving a shock to the earth altered their situation, and by this means set them at a greater distance. But that notwithstanding this, the great magazine of ice formed before this terrible shock still remains, nor has the heat of following ages ever been able to melt it. Hence proceed the sharp colds and a stronger refraction caused by them.

Certain English sailors, who, above a century ago, endeavoured, without success, to find in North America a passage to the southern sea, were obliged to spend the winter in an island very little more north than London. Every thing there was transformed to ice, the house they had built, the sea, the ship, and even themselves.

They were obliged to cut the most spirituous wine with a hatchet, and the refraction was so strong, that they observed the rising moon of an oval figure extremely long, and the sun when at the horizon to be twice as big in breadth as in length. The air was sometimes so very clear in the depth of that severe winter, that they discovered more stars by two thirds than are usually seen, and the milky way appeared evidently to the naked eye, a collection of stars. Thus in these countries there would have been no need of a Democritus to conjecture it among the dreams of the ancient philosophy, nor a Galileo to verify it by the assistance of the telescope.

From a great number of experiments made in England, it evidently appears, that the refractive power of the air increases in proportion to its density, which is true likewise in other mediums which refract the light, but however with some exceptions. Air, water, and glass, sensibly observe this proportion. But oleaginous and sulphureous liquors, and which consequently are combustible, have a greater refraction than liquors of another nature even tho' they are more dense. ^{from the air} Oil which is less dense than water, as appears by its swimming upon it, has however a greater force in refracting the light.

Alas! interrupted the Marchioness, I am a great enemy to exceptions, and I have a most mortal aversion to the *but* in conversation. Every one who takes it into his head to

rail against our sex before our very face, will doubtless except, with a constrained *but*, her who has the misfortune to be present. Satire, so agreeable to the malignity of our mind, becomes cold with these exceptions; our self-love is not sufficiently flattered, and truth loses too much when it becomes less general.

Exceptions of this sort, answered I, are properly only new truths which arise from the discovery of many causes, which joined together generally concur to produce a certain effect. This greater refraction in a less density of medium arises from another particular correspondence between these liquors and light. It acts upon them more than upon any other sort, by agitating, warming and inflaming them more easily. It is just then, on the other hand, that these in return should act more upon the light than other mediums do, by breaking and refracting it in a greater degree.

May we not conclude from hence that this force resides chiefly in the sulphureous parts of bodies? For this reason boiling water, in which these parts are more disengaged, has a greater attractive force than cold water.

In general, warmth and rubbing augment the attractive force which is in bodies, or make it appear in a particular manner. Amber, all sorts of pellucid gems, glass, hair, and many other things when they are rubbed, discover the force called *electrical*, and which is communicated to other bodies, carried to incredible distances, and whose effects are surprizing beyond all belief.

If a tub of glass be rubbed till it grows hot, it will attract light bodies, as leaves of gold or cotton, and afterwards drive them at a distance. It will raise a sort of tempest in a heap of little pieces of burnt paper, by attracting and

then tumultuously repelling them from itself. In short, this force is a species of magic wand, that communicates and awakens a power in bodies, which had before lain dormant and inactive.

A ball of ivory fastened to a cord of nine hundred or a thousand foot long, acquires the same power of attraction and repulsion, if the electrical tube be applied to the other end of the cord a thousand foot distant. You had very great reason, replied the Marchioness, to call this tube a sort of magic wand, for it really produces incomprehensible effects. At least, it is a mystery to me that it should with such rapidity draw the little bodies to itself, and afterwards with a sort of disdain remove and drive them away.

Observation, answered I, which has hitherto been our guide and clue in the intricate labyrinth of natural philosophy, will continue to give us the same assistance in that little way we have yet to go. It has conducted us to the discovery of new properties in light and colours, which have opened a new scene of optics to philosophy. It has conducted us to the discovery of attraction in the most secret retreats of bodies; which is likewise a new and surprising quality of matter, by which all natural philosophy is changed and renewed; and now this faithful guide leads us to *repulsion*, whose effects in nature are no less considerable and surprising.

Are we not to impute it to this force, that flies are able to walk upon the water without wetting their legs, and that the particles, which fly off from bodies by means of heat or fermentation, are set at so great a distance from each other as to possess an infinitely greater space than they did at first?

The air after being compressed may be dilated to such a degree as to possess a space more than eight hundred twenty six thousand times greater than it did when compressed, and this without being heated, which would dilate it still more. That you may understand this force has no less influence in heaven than earth, the famous comet of 1682, approached so close to the sun that it was heated two thousand times more than a red hot iron. The vapours arising from it, and cast at a distance from each other by the repulsive force, adorned it with so formidable a tail that it took up in heaven the length of eighty million of English miles. It would have been very bad for us to have been near, and involved in it; for instead of gaining a ring or another moon, we should have been calcined and burnt to ashes, like a little stone in the focus of a burning glass.

Some persons so taken up with the phantoms of the uncertain *future*, as not to see the fugitive *present*, expect that one day some comet will cause the universal conflagration of this globe. Comets have perhaps anciently produced a deluge, have struck against the earth and overset every thing in it, and who knows but one time or other they may bring a conflagration upon it, after which laying aside its old spoils like the snake, it may again grow young and be renewed, and our great theatre change both its scenes and actors.

The present, replied she, is so various and agreeable as it now stands, that I am greatly deceived, if it may not divert us as yet a long time without any change.

But perhaps it is to these comets that we are obliged for one of the finest changes, and what we every day enjoy. They are perhaps the ingenious mechanicks that

have rendered our theatre capable of being turned round like that of Curio, so famous in antiquity, where the Roman people, the conquerors of the world, the race of heroes, and the portion granted to mankind by the immortal gods, sat upon a frail machine, in which they could not even applaud their public shews without danger. We at present perhaps owe to some comet, without apprehending any calamitous accident, the rotation of our earth, the perpetual and constant succession of light and shadow; in short, the pleasing variety of day and night. One of these perhaps by giving us a shock has occasioned this motion in us as well as the other planets which are discovered to be endowed with it.

Before this we had, like the cold inhabitants of the pole, six months day and six months night, but without gaining like them either a strong refraction or a long twilight to anticipate and prolong our day. A little moon-light would from time to time have faintly illuminated that long and melancholy darkness. What optics, what colours could we ever have had for six continued months, unless the comet with its shock had lent us its assistance? Since every thing, replied the Marchioness, stands well at present, heaven guard us for the future from the proximity of any one of them, from the shocks, the conflagrations and the deluge with which they menace us, and from that repulsive force that renders them so very formidable. But are not these the riddles as well as terrors of natural philosophy, that the same bodies should be both attracted and repelled?

I do not know, answered I, after some pause, whether I ought to introduce you any farther into the sanctuary of the Newtonian philosophy. There are in this certain my-

steries still deeper and more sublime than those to which you have already been admitted. You should now invoke those spirits the first-born sons of light, the guardians of those secret truths which they imparted to our philosopher, that they would suffer me to discover to you things concealed from the sight of mortals, and deeply immersed in a gloomy mist and the most profound night. You must now entirely divest yourself of those few remains of profaneness which may still attend you. Tell me, Madam, what courage do you feel for truth? The same, answered she, that a brave soldier feels to follow his captain wherever valour calls. I follow you without fear wherever truth leads the way.

You appear, answered I, to think it a riddle in philosophy, that the same bodies should be both attracted and repelled; and indeed there is some reason for your thinking so. But would not the riddle be still greater, if I tell you that these two contrary forces, the attractive and repulsive, are of the same nature, and in short it is only the same force which discovers itself in different manners and various circumstances? The Marchioness, at this, could scarce forbear laughing. What! said she, do you call the attractive and repulsive force the same thing? One acts directly contrary to the other, since the first attracts and the last repels. Are these those sublime mysteries in natural philosophy, of which you hardly thought me worthy, and which you have introduced with so much apparatus? Does not all this greatly resemble the physician in Moliere, who affirmed roast and boiled to be the same thing.

What! answered I, do you ridicule the most sacred things in natural philosophy, and of whose use you are

yet ignorant? What a spirit of profaneness still remains in you! but you shall quickly be punished. Remember the conclusion which you yourself just now deduced from that very attraction you made so great a difficulty to admit. Ladies of all persons have least reason to be surprized that the same thing should produce contrary effects. Do not the highest reserve and an evident partiality often proceed from the same principle, and teach connoisseurs to draw the same conclusion from them? The sun hardens and softens according to the different circumstances in which he exercises his heat.

This truth is no less evident in the most noisy affairs of human life, than in the phenomena of gallantry and natural philosophy. The same thirst of leaving an empty name and living in the imaginary breath of posterity, burnt the temple at Ephesus in Asia, and precipitated a Roman and his horse into an open gulph in the midst of the forum at Rome. The same passion made Curtius an hero, and Erostratus an incendiary.

There are certain things which to the vulgar, nay even the philosophical vulgar, may appear as evident contradictions in the same man, whom some upon that account have imagined to be double, as others did the governor of the universe, so that what the one willed, the other disapproved: but are not these contradictions the necessary consequences of the same passion and the same motives?

Thus the very same cause, by which bodies are attracted, may in some circumstances repel them. There are found certain analogies between these two forces, which give us great reason to conclude that they are in reality only the same force which produces different effects.

It is generally found that where the attractive force is

weak, the repulsive too is weak, and where the one is strong, the other is strong also. Refraction which depends on one of these two forces, and reflection on the other, are both effected where there is a surface that separates two bodies of different density. For while the rays proceed in the same medium, and do not meet with one of a different density, they are neither reflected nor refracted.

Those rays, which are most refrangible, are likewise more easily reflected than the rest. In bodies by which the light is more refracted, it is likewise more strongly reflected. And in general where the attracted force is greatest, the reflective and repulsive is greatest also. Diamonds, which refract the light very strongly, give it in proportion a stronger reflection. Hence proceed the vivacity of their colours and their fine sparkling lustre.

These analogies, replied the Marchioness, are very pretty and very good, and so are the examples by which you introduced them, and very strongly reproach my rashness. I am heartily penitent for my fault in laughing, when I should have admired, and despising what I ought to have regarded with veneration. But did not you tell me that reflection happens when light meets with the solid parts of bodies, and is from thence repelled? This explication seemed very intelligible to me, and perhaps more so than what you at present intimate.

It is Des Cartes, Madam, who gave you this explication, and not I, therefor you may be in some apprehensions about it. An ingenious author gives a very useful piece of advice, that in philosophy we should be as diffident of what we imagine ourselves to understand very easily, as of what we do not understand at all.

If refraction was made when the light meets with the

solid parts of bodies, as you so clearly understand it ought to be, do you know what an inconvenience would from thence arise in nature? you would no longer have either toilette or looking-glasses.

A surface, however smooth and polished it may be, is however full of protuberances and sensible irregularities discoverable by a microscope. Imagine all bodies which you believe the most smooth and polished, to be like water when it is ruffled by the wind. The light must be reflected from all bodies irregularly as it is from water thus ruffled, and could never be sent back with that regularity as is necessary for you to see yourself in a looking glass. Is not this paying a great price for your fine explication? Is it really true, answered she, that it will cost so dear? Perhaps you put me into a greater terror than the danger deserves. Is it not possible that these irregularities in the surfaces of glasses, though sensible to the microscope, may yet be insensible to the light?

You are grown extremely difficult, Madam, answered I. The protuberances and cavities in the most smooth and polished glasses, are when compared to a particle of light, what the Alps or Pyrenees would be in respect of a tennis-ball. The irregularities of a looking-glass are discoverable by common microscopes, but there is no microscope so perfect as to shew the pores of diamond, through which the light however passes very copiously. It would be a terrible circumstance for us, if the particles of light were not almost infinitely small. The force of bodies is reckoned from the quantity of matter that they contain, which is called the mass, and from their velocity; the greater therefor their mass and velocity, the greater is their force.

The particles of light have an incredible velocity, for they come from the sun to the earth in about eight minutes, and thus in eight minutes they run through a space of eighty one million of miles. Their velocity then being so extremely great as to exceed more than ten million times that of the swiftest English horses, their mass must be almost infinitely small, or else a single particle of light, instead of animating and reviving all nature by its appearance, would produce upon our earth the most terrible effects of a cannon.

The good effects, answered the Marchioness, of that diffidence we ought to shew to men, extend likewise to philosophers; for by this means the one gives greater proofs of what we desire should be true, and the other of what really is so. I will for the future be very careful not to believe you too hastily.

For this time at least, answered I, you cannot accuse yourself of too much credulity. It will never burthen your conscience that you have not had sufficient arguments to believe that reflection is not made by the meeting of light with the solid parts of bodies. For besides the great inconvenience which would arise if this supposition were true, observation informs us, that light, transmitted through a piece of glass, suffers a stronger reflection at going out of the glass than it did at entering into it. Now how is it possible that light should find more solid parts in the air than in the glass itself, to occasion this stronger reflection?

Besides, if water or oil be placed immediately behind the glass, the reflection becomes weaker. Will the light find fewer solid parts in water or oil than in air?

Lastly, if the air which is behind the glass be taken a-

way by an instrument made for that purpose, the reflection will be much stronger than it was before the air was removed. Will you say that light meets with a greater number of solid parts in a vacuum than in the air? Heaven forbid that I should say it, replied the Marchioness; I will rather make the repulsive force to be the cause of reflection. In these cases, answered I, it is not the repulsive but the attractive force. When a ray goes out of the glass into air, it is attracted by the air and the glass; hence that part of it, which was nearest the glass, returns back as if it had been reflected; if the air be entirely taken away, this part being extremely attracted by the glass, and hardly any thing by what remains after the air is removed, it returns back again almost entire.

But if water or oil, which attract the ray much more strongly than the air does, be placed behind the glass, a less part of the ray will return back than there did while the air remained. Lastly, when the forces of the two mediums are balanced, as for instance, if a liquor be applied to the glass of pretty near the same density, or another piece of glass, the ray must pass entire, and there will be no reflection.

In general, we may affirm that the attractive force is the cause of the reflection of the rays, when the light passes from a dense into a rare medium; and the repulsive, when it passes from a rare to a dense.

In both cases, since the attractive and repulsive force are propagated at some distance from bodies, the light is reflected notwithstanding its distance from the reflecting body. Just as when it begins to be refracted, it is somewhat distant from the refracting medium, in the same manner as it is from the extremity of bodies when passing near

them, it is turned out of its direct path and curved by diffraction. Hence you see that solid parts and Des Cartes's explication have less to do with reflection than ever.

Poor Des Cartes, continued she, is attacked in his very last ⁱⁿ retrenchments. There is nothing wanting to complete his overthrow but for us to assert, that as light is not reflected from solid parts, so neither is it transmitted from the pores of bodies; and thus he may return back like that momentaneous Alexander of the north, who, after the most rapid and noisy victories, at length lost the best of his own dominions.

In order to deny him every thing, and give him leave to return home as soon as he pleases, we will at least deny that the quantity or magnitude of the pores in bodies, contributes any thing to their transparency. It is proved on the contrary, that if the pores of a body, for instance, paper, be filled with water or oil, it loses its opacity, and becomes transparent; whereas if the pores in a body be multiplied, as when glass is reduced to powder, it loses its transparency and becomes opaque.

It is in homogeneity we are to seek the cause of transparency. If there be many pores in a body, and these be filled with a matter different from that of the body itself, the light will meet with a thousand reflections and refractions in the internal parts, and thus it will be utterly extinguished. The air ceases to be transparent when it is cloudy, though it is then lighter than when it is clear, and consequently more porous. Its opacity can rise from no other cause but that it is at that time heterogenous, which makes the rays that pass through it suffer innumerable reflections and refractions, by which means they are very soon stifled and extinguished. Thus the froth of Cham-

pagne is opaque, though much more porous and lighter than the wine itself.

This seems to furnish us with an argument to infer, that the heavens cannot be filled with matter however rare it be supposed, even if all contained within the vast orb of Saturn, and though its pores should be as small as you can possibly conceive, it might, after being perfectly united so as to leave no empty space, be grasped in one hand.

What strange relation is this you tell me? replied the Marchioness. Is the Newtonian philosophy some golden fleece which we must not undertake the conquest of, till we have first passed through a thousand strange portents, and subdued a thousand monsters of imagination.

Do you believe, answered I, that gold the precious substance for which mankind do and suffer so much, and for which we feel the greatest thirst when we ought to be most satisfied, gold I say, and diamonds themselves, the most shining work of nature, notwithstanding their great weight and gravity, contain a great quantity of matter? It will appear strange when I tell you how very little that quantity really is when compared to that vacuum between the parts, and which to our deluded eye seems perfectly full.

The solid parts, contained in a piece of glass, are no more considered with regard to its extent, than a grain of sand to the terraqueous globe. It is very surprizing how little solid matter there is in the world, and with how few materials, if I may use that expression, it is built. Perhaps if you knew the truth you would be afraid you walked upon cotton, and were in danger of crushing it under your feet, even if they were as light as those of the swift Camilla.

Now if the matter of the heavens be imagined uncon-

ceivably rare and subtle, yet the light, which, notwithstanding its prodigious velocity, employs according to the last calculations six years in coming from the stars to us, must be intirely extinguished by that multiplicity of reflections and refractions which it must suffer in that immense passage; just as a numerous and flourishing army, in a long march, must decrease and perish by the fatigues and obstacles it meets upon the road.

I see with pleasure, said the Marchioness, how the properties of our light conduct us to empty heaven, and after having set the earth in motion, to clear its way. The diffractions too, answered I, which the light would suffer from the particles of this celestial matter, would contribute not a little to extinguish it, in the same manner as they would do in bodies that are very porous and heterogeneous. It is surprizing that in the notes which Perrault wrote upon Vitruvius, he seems, if I remember right, to have had some faint notion of this truth. Rarefaction, said he, that is, a distance of parts, renders bodies opaque, because these which were at first homogeneous, when rarefied, become heterogeneous.

It seems much more surprizing, said the Marchioness, that any person could clearly see and demonstrate that two things so very opposite as reflection and refraction should yet arise from the same cause: this I must confess will always be a wonder to me.

The facility, answered I, and the obstacles which the light meets in passing out of one medium into another, are almost in the same case. Perhaps an exceedingly subtle fluid diffused in the confines of the mediums, extremely quick in its vibrations, and in which the light by percussion excites an undulating and tremulous motion, as a stone does

in water, or a voice in the air, is the cause of both the facility and obstacles in question. Thus if the light happens to be in the concavity of the waves of this fluid, it passes freely through it, but if in their summit, it is drove back again.

Hence come the *fits of easy transmission and refraction*, that is, the same ray of light is in one moment transmitted, and in the next reflected; and because the vibrations of this fluid are exceedingly rapid, the rays appear to us both transmitted and reflected at the same time.

But we are now arrived to the confines of nature, where our ideas grow dark and confused: these are the barriers of knowledge, beyond which no force of human faculties is permitted to proceed. I myself perhaps have run too great a length.

Sir Isaac Newton, under the form of questions, proposed many things which are probably the recesses where nature withdraws to conceal herself from mortal eyes. The analogy betwixt sound and colour, the strange metamorphoses of light into bodies, and bodies into light, the two-fold and surprizing refractions of island chrystal, rock chrystal, and that sort lately discovered in Brasil, will always be impenetrable enigmas to mankind, since this Oedipus was not able to solve them.

How very different from the modest doubts of this legislator of the wise are the rash assertions of the seducers of the multitude. These however promise those very men, whom they have always deceived with the same flatteries, to open the temple of truth so often tried in vain, in the most expeditious and easy manner by the help of certain new principles; just as others with certain new systems of their own spread artful nets for human avarice, and pro-

mise at once to enrich a nation which they have always impoverished by the very same schemes. The pleasing and vain delusion of hope leads some in haste to the *bank*, others to the academy. The beginning of an affair is generally agreeable to our flattering expectations. The wind is commonly favourable to the ship just loosed from the port, and two bright eyes give an agreeable invitation at the first appearance. The bank by converting hopes at first into gold preserves and increases its reputation; and philosophy by judicious prefaces maintains its honours, more successful in banishing old errors, than substituting new truths in their place. Thus they, who by a prudent diffidence soon extricated themselves from the snare, either brought back a reputable increase of their fortune, or were rationally delivered from their past prejudices. But there are very few so wise as not to lose the present in forming projects for the future, or not to make the happiness of to-day, a step to the misery of to-morrow. The cheat at length is discovered, and the first are left with their scrutoirs, full of notes worth nothing, while the last have their heads embarrassed with notions of pressure, rotations, globules and vortices, the false coin of philosophy. Sir Isaac Newton, guided by a slow yet sure experience, promises no more than what experience is able to perform. Where that leaves him he stops; by its assistance he distinguishes truth from falsehood, evidence from probability, and in the extent of his *own*, discovers the limits of the *human* understanding.

Are not the rays of light, says Sir Isaac Newton, very small bodies of different sizes, the least of which make violet, the weakest and darkest of all the colours, and more easily diverted by the attractive force of the *prism* from the

right path? And the rest, as they are bigger and bigger, make the stronger and more lucid colours, blue, green, yellow and red, and are more difficultly refracted, in proportion to the greater strength of the colours, and the larger size of the bodies that compose them?

It is certain that the rays of light differ from each other in colour, refrangibility, and the force with which they strike our senses. Scarlet dazzles the sight, the azure of heaven languidly moves it, and the verdure of a meadow strikes it with a very pleasing sensation.

Only one of these differences, said the Marchioness, had been sufficient to make an ordinary philosopher put an absolute difference in the size of the particles of light, whereas two or three are hardly enough to supply ours with a conjecture.

In the vast and unlimited perspective of nature, answered I, there are objects that we are for ever condemned to see languid and confused, without hoping that any telescope can make them appear either less distant or more distinct. The moderation of our philosopher, in never affirming any thing to be true which was not demonstrated by observation, may serve for an example to the most rash asserters. Who could have more reason to think himself capable of ascending heaven, or bringing the secrets of nature in triumph from thence, than Sir Isaac Newton, who, poised upon the wings of geometry, could take his flight through immense spaces, till then impenetrable to human curiosity?

What a strange condition, replied the Marchioness, is ours! We know what size in a particle at a great distance from our sight is necessary to reflect a certain colour; but, what is this colour itself which we have always immediately

before our eyes? Hardly can we form any idea of it by a feeble conjecture: In one case we have the sight of a lynx, in the other we are absolutely blind. There our senses are refined beyond what we could have expected; here they seem to abandon us all at once.

There are some persons, answered I, who have believed that the many difficulties which attend our little degree of knowlege, the great number of systems, the various emblems of human ignorance, and that continual tantalizing which philosophers suffer in their searching after truth, proceed from no other cause than our want of a sixth natural sense which might reveal a great part of what is at present hid from us, and escapes perhaps those five senses given us by nature to lay hold on external objects, and bring them to the mind.

As there are certain animals among us, who, by virtue of senses, of which we perhaps have no knowlege, foresee the change of the seasons, and approach of the morning, and, without having read Dioscorides or any other botanist, can amidst a thousand others distinguish that salutary herb that cures their hurts; who knows but in some other system, in the world of Jupiter perhaps, there may be animals which, more sharp-sighted than our philosophers, may discover the size of those particles that compose the variety of colours, and in what manner, without the assistance of ropes or pulleys, they may attract Saturn at a distance of more than three hundred and fifty millions of miles?

But in return, as in that planet, which is not depopulated by the race of war, the inhabitants have no idea of the pleasures of love, so, according to the agreeable historian of these worlds, every thing is diversified, and put in

a just balance; those people, who are thoroughly acquainted with the nature of colours, may perhaps want the sense proper to give them a perception of the most agreeable harmony of those colours upon the cheeks of their *Chloes*; and though, perfectly skilled in the attractions of the planets, are perhaps insensible to the more pleasing attractions of beauty, which are preferable to any speculation whatever.

But however it be with regard to our present speculation, the most vain perhaps of all others, it is not for our advantage to seek occasions to put us in mind of our defects, nor be so ingenious in tormenting ourselves. We shall not be destitute of either knowledge or pleasure, if we make a good use of the senses fallen to our lot. Though you know nothing wherein consists the nature of light and colours but by conjecture, there will not perhaps be wanting some persons to affirm you know much more of it than is proper for a lady. The fault will be thrown entirely upon me, who upon those few verses which give occasion to our subject, have made you a comment long enough for a poem upon the Newtonian philosophy. It will be well for it, if you dissemble your knowledge with those persons who ridicule what they ought to learn, and if to the science of natural philosophy you join that of the world.

What, cried the Marchioness, am I so learned that I ought to study to be ignorant? May I venture seriously to call myself a Newtonian? You have already renounced your philosophical errors, answered I. The light of Newtonianism has dissipated the Cartesian phantoms which deluded your sight. You are now really a Newtonian, and it is no small advantage to *truth* that you are so. I will some time give a history of the fine conquest I have acquired

for her, and I am certain if I could give a just description of my fair disciple, my book would never want readers nor true philosophy a numerous train of profelytes. You shall be the Venus that must lend the agreeable Cestus to this austere Juno, and give her those attractive charms that will render her engaging and amiable to mankind.

T H E E N D.

Mistakes to be rectified.

Page 73. line 28. *for* : not, *read* . Not.

ib. l. 31. *for* . Did, *read* ; did.

81. l. 7. *for* deeper, *read* higher.

180. l. 10. *for* article, *read* Ancile.

205. l. 8. *for* not, *read* and.

227. l. 2. *for* barel, *read* barely.

257. l. 11. *for* particles, *read* parts.

ib. l. 28. *for* presents, *read* preserves.

261. l. 27. *for* even though they are more dense, *read* even though they are more dense than the oils.

x 173 for gives read gives
177 for gives read gives



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